Update from The Pennsylvania State University

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T

Impact of shale gas wastewater disposal on Conemaugh River Lake sediments

Dr. Bill Burgos, Dr. Nathaniel Warner, Luis Castillo Meza, PhD candidate in Environmental Engineering

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Dr. Thomas Borch, Departments of Chemistry and Soil and Crop Sciences, Colorado State University

Rose Reilly and Carl Nim, US Army Corps of Engineers, Pittsburgh District

Conemaugh River Lake, Pennsylvania

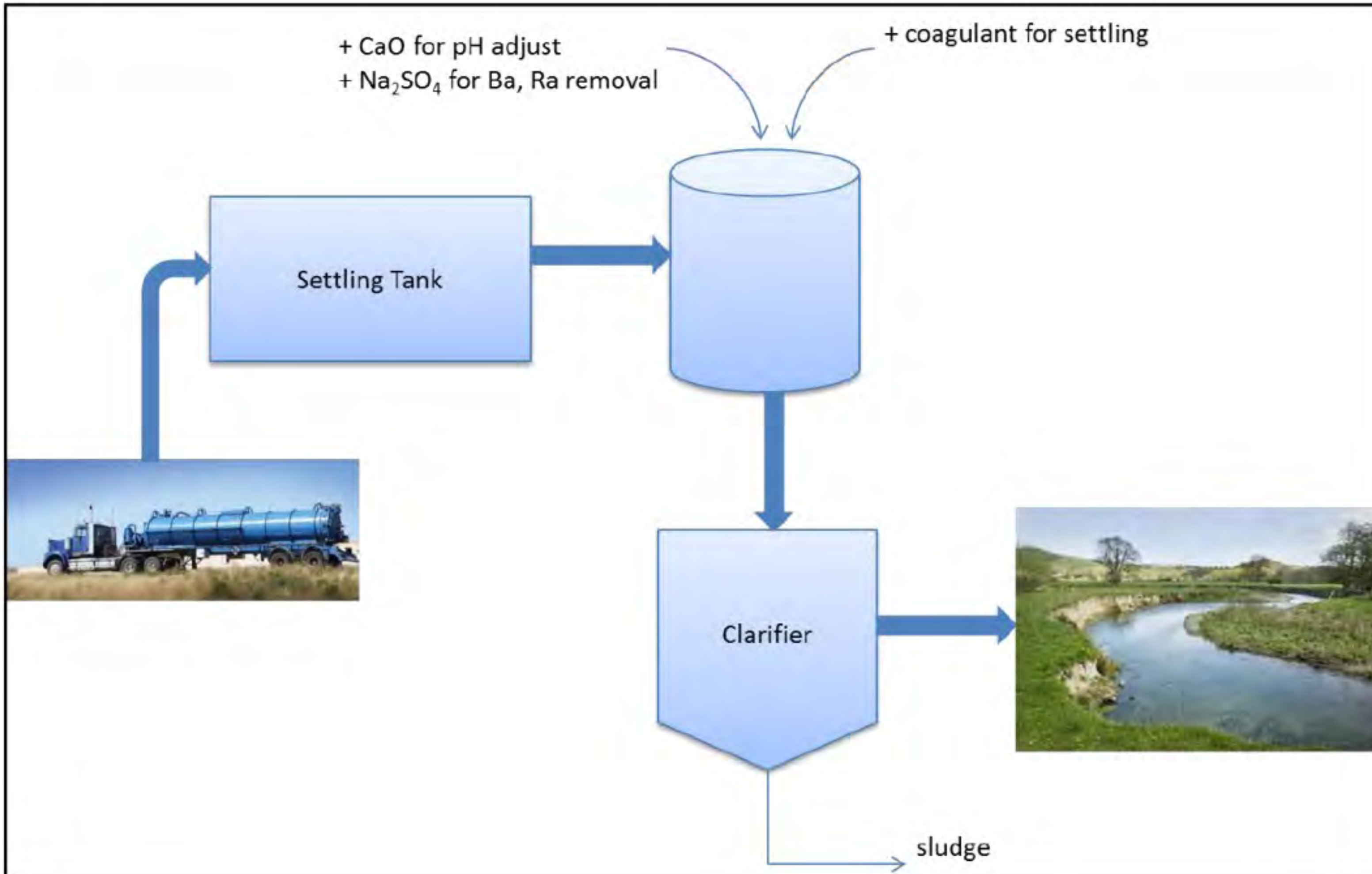
https://en.wikipedia.org/wiki/Conemaugh_River

Flowback and produced waters contain many contaminants of concern

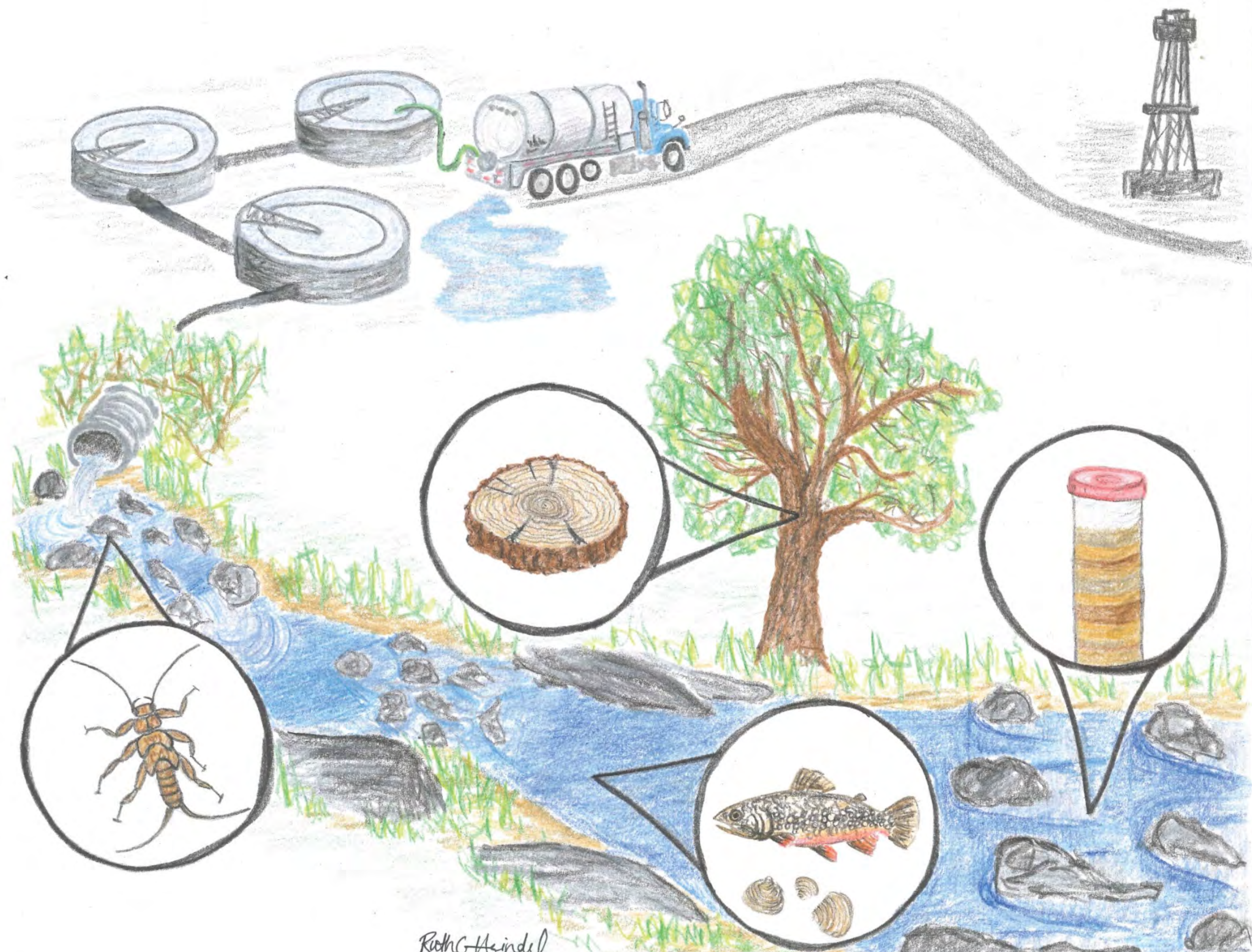
Contaminants of concern	Units	Minimum	Maximum	Average
TDS	mg/L	680	345,000	106,390
Cl^-	mg/L	64.2	196,000	57,447
Br^-	mg/L	0.2	1,990	511
Ba^{2+}	mg/L	0.24	13,800	2,224
Sr^{2+}	mg/L	0.59	8,460	1,695
^{228}Ra	pCi/L	0	1,360	120
^{226}Ra	pCi/L	2.75	9,280	623
Oil and grease	mg/L	4.6	802	74
COD	mg/L	195	36,600	15,358

[Barbot et al, ES&T 2013]

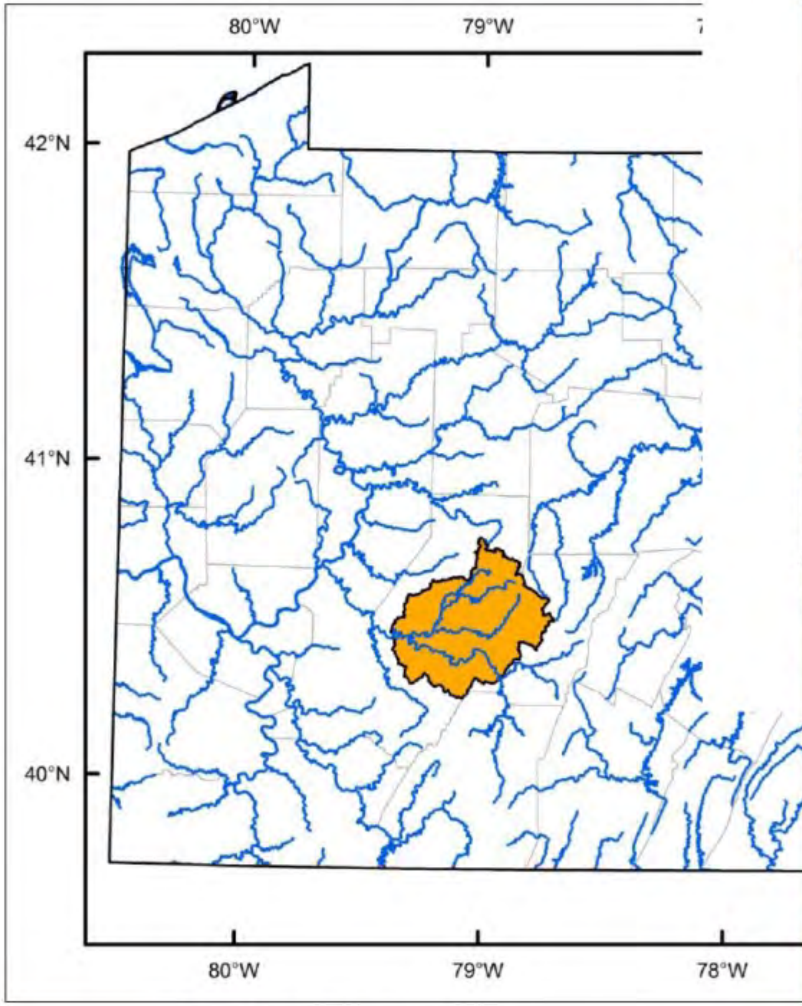
Centralized waste treatment plants are not well equipped to remove all oil & gas contaminants



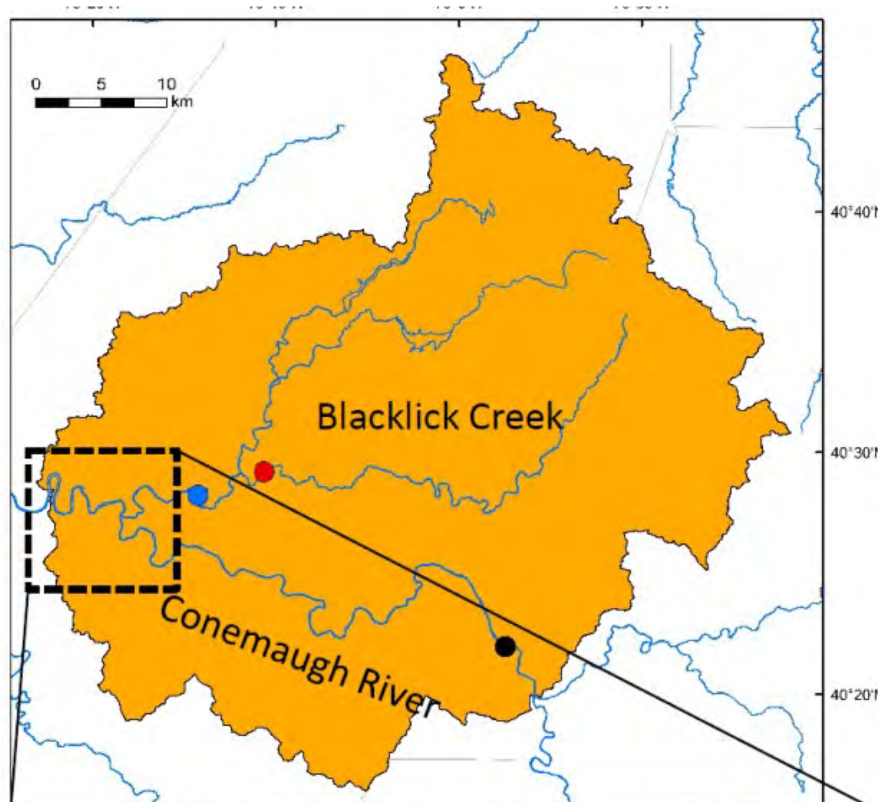
Surface water discharge of oil & gas wastewater can affect aquatic and human health

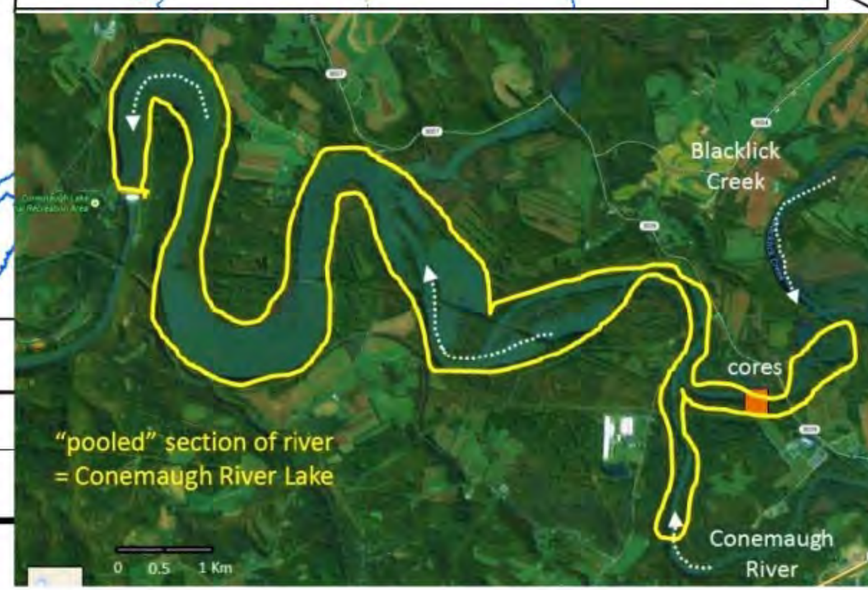


- Fluid Recovery Service Josephine Facility
- Howard Treatment Facility
- Dornick PT Sewage Treatment Plant

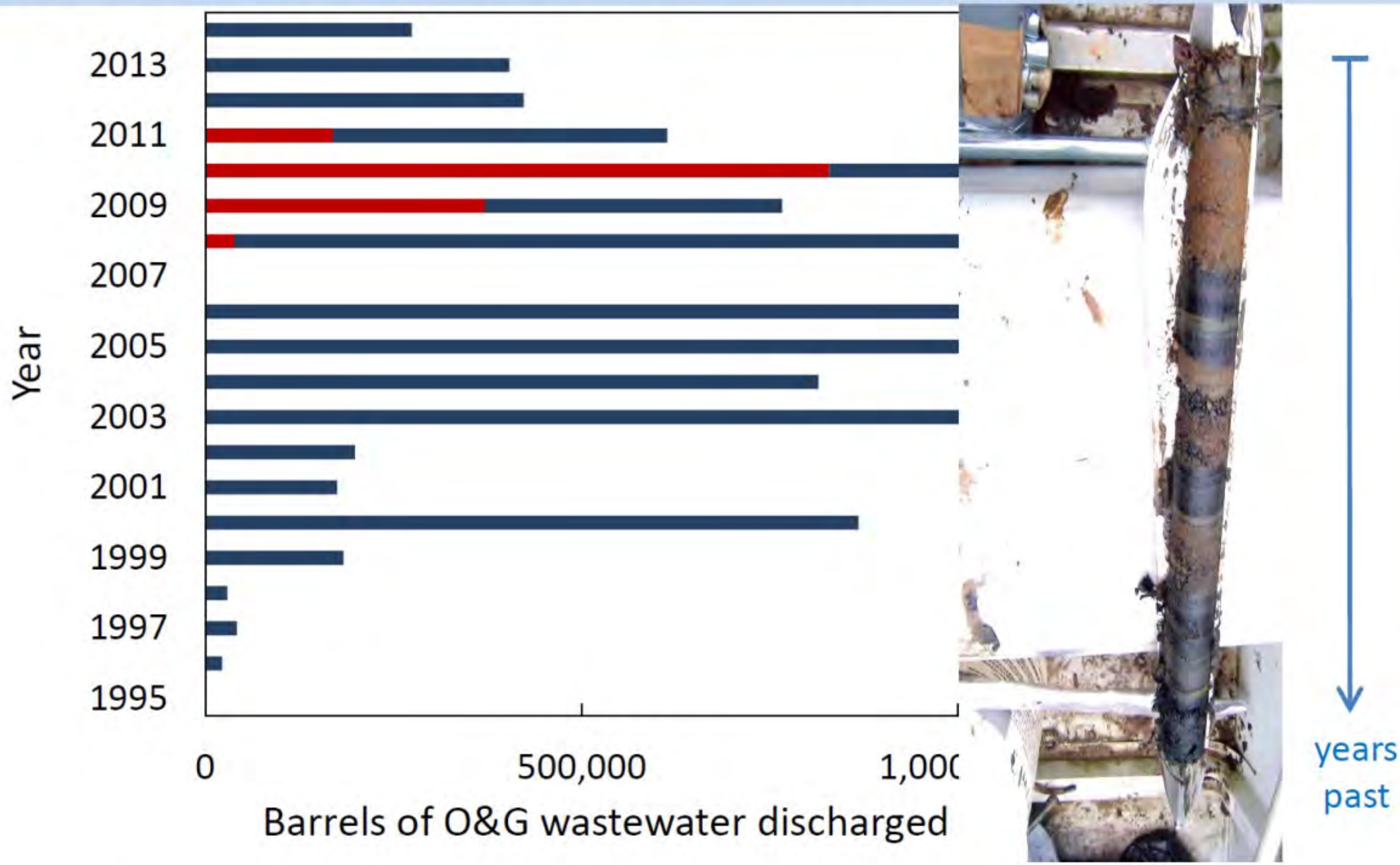


[www.pasda.psu.edu]





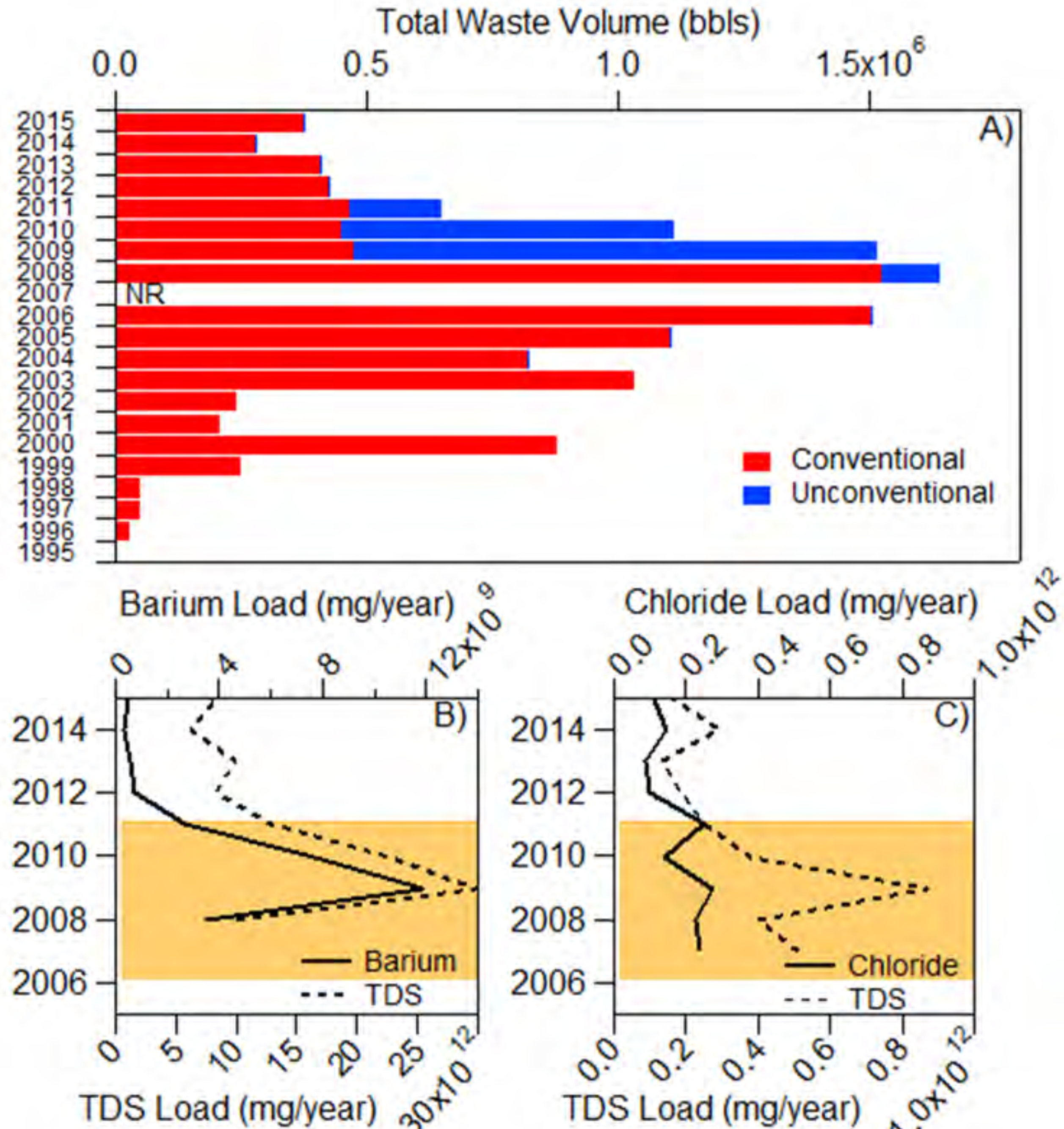
Research Hypothesis – Historical impact of upstream CWTs will be evident in the sediment record of the Conemaugh River Lake



[https://www.paoilandgasreporting .state.pa.us]

Intact sediment cores were collected from Blacklick Creek with help from the US Army Corps of Engineers

Sediment cores were immediately ‘flash frozen’ on dry ice, then stored and transported in freezer trailer

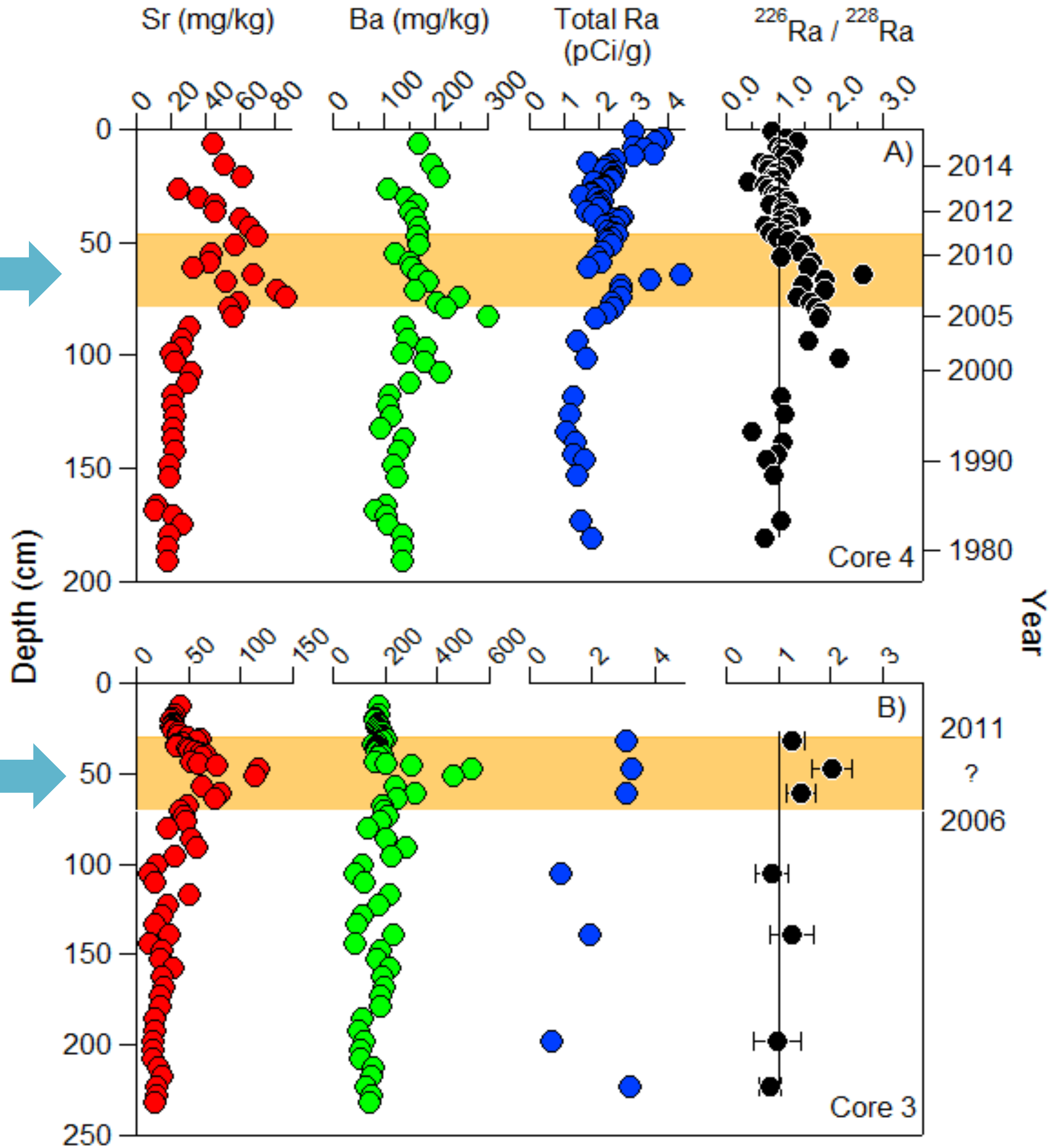

Total Waste Volume (bbls)
0.0
0.5
1.0
1.5x10^6
A)
2015
2014
2013
2012
2011
2010
2009
2008
2007
NR
2006
2005
2004
2003
2002
2001
2000
1999
1998
1997
1996
1995
Conventional
Unconventional
Barium Load (mg/year)
0
4
8
12x10^9
B)
2014
2012
2010
2008
2006
Barium
TDS
0
5
10
15
20
25
30x10^12
TDS Load (mg/year)
Chloride Load (mg/year)
0.0
0.2
0.4
0.6
0.8
1.0x10^12
C)
2014
2012
2010
2008
2006
Chloride
TDS
0.0
0.2
0.4
0.6
0.8
1.0x10^12
TDS Load (mg/year)

Concentration profiles of alkaline earth metals.

SOILS

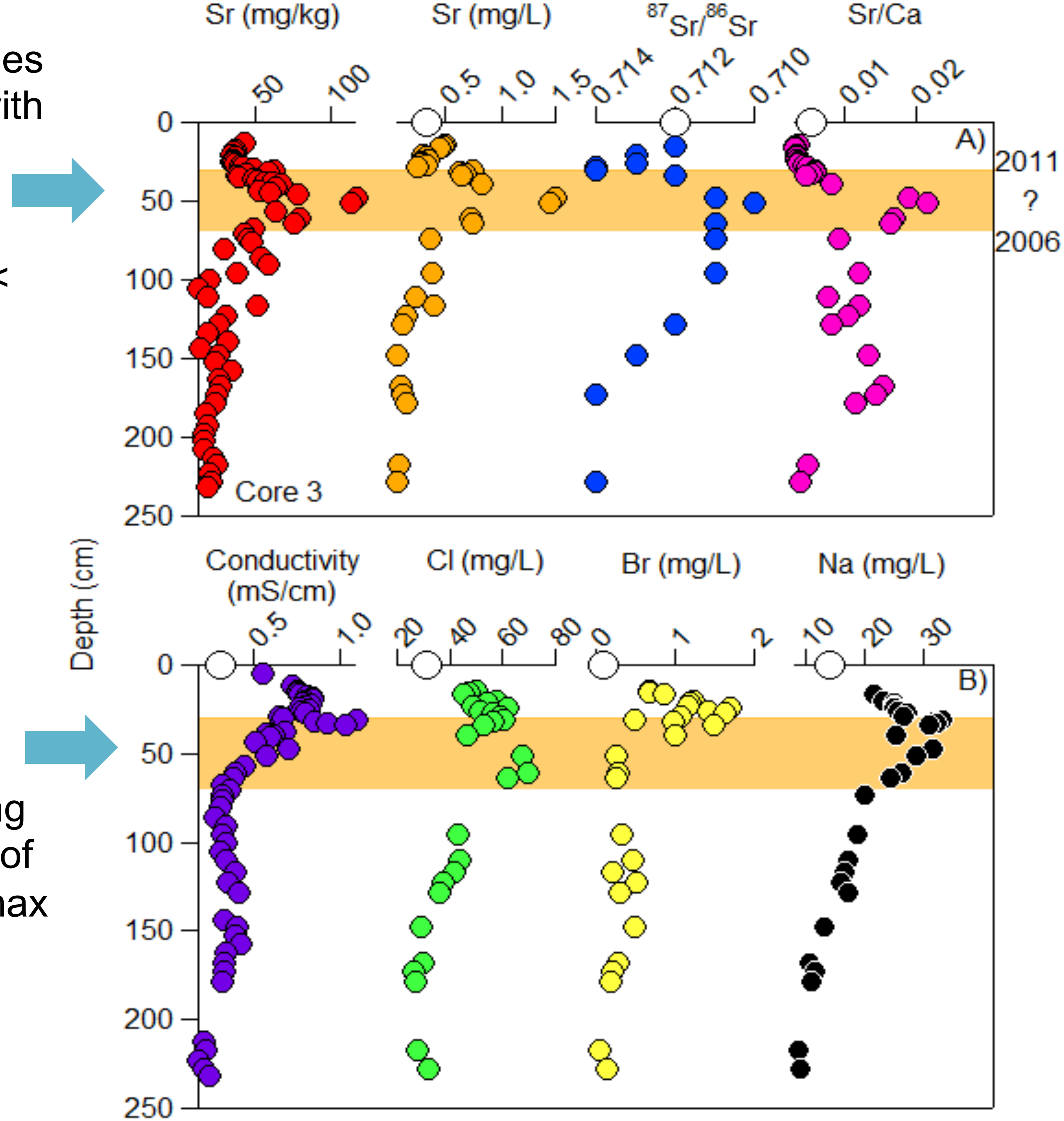
226Ra/228Ra isotope ratio > 1 indicative of Marcellus Shale.

POREWATER



Contaminant depth profiles of sediment porewater with Sr isotopes.

87Sr/86Sr isotope ratio < 0.711 indicative of Marcellus Shale.



Porewater profile showing elevated concentrations of salt that correspond to max discharge of Marcellus Shale wastewater

Preliminary conclusions

- Convergent lines of evidence reveal legacy of chemical constituents (Ra, Sr, Ba, Cl, surfactants) discharged from O&G wastewater facilities

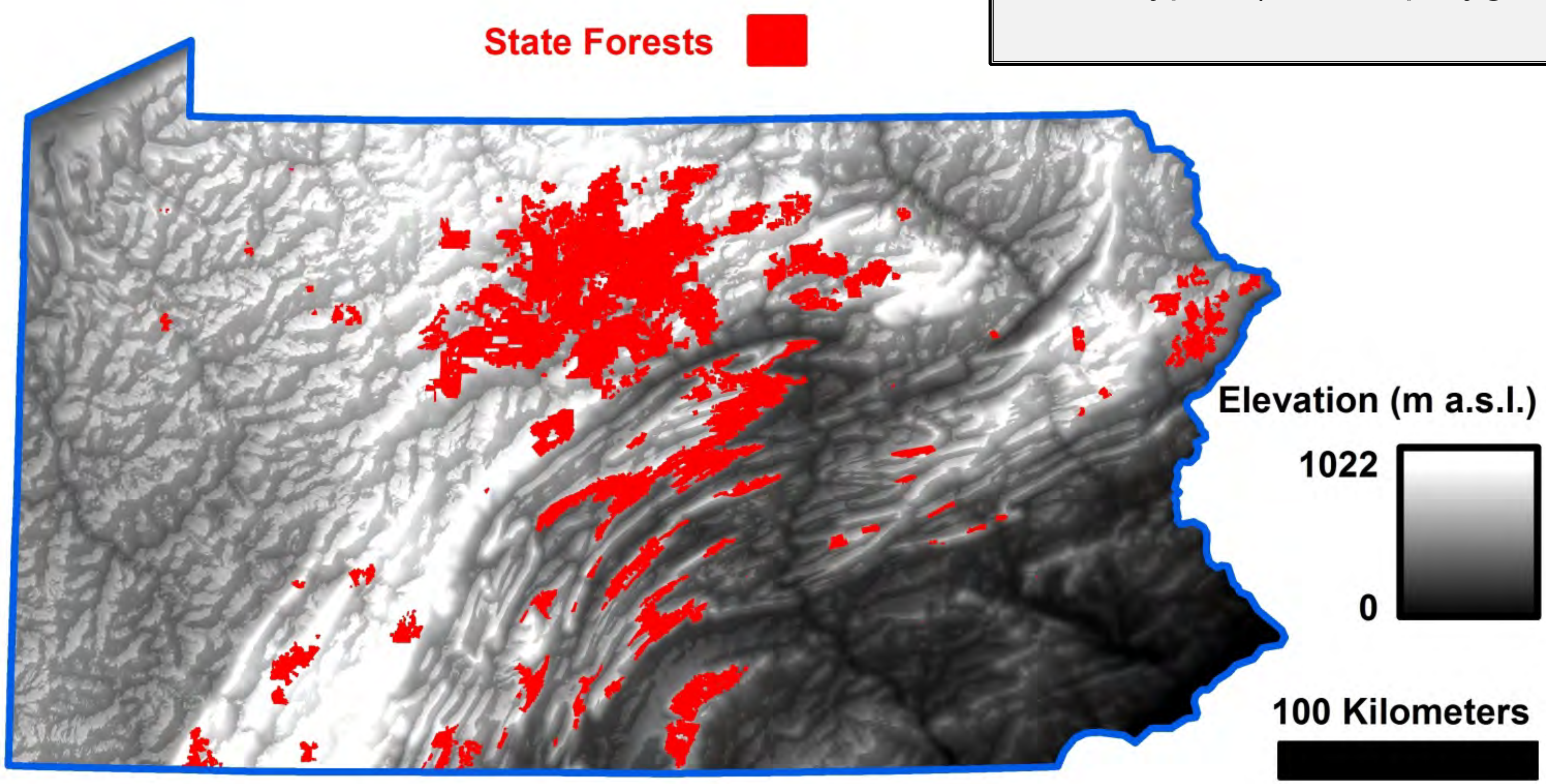
Identifying Forested Ecological Sites

Rapid Delineation of Ecological Sites
Ireland and Drohan (2015) SSSAJ

Methods

Pennsylvania State Forests

1. ~918,000 ha
2. Mapped in its entirety
3. ~815,000 ha (89%) terrestrial forest communities
4. 20 types (58,261 polygons)



Methods

20 Forest Types (i.e. Communities)

ID	Descriptive Name
AH	Dry Oak - Heath Forest
BB	Northern Hardwood Forest
AR	Red Oak - Mixed Harwood Forest
AD	Dry Oak - Mixed Hardwood Forest
CC	Red Maple Forest
BC	Black Cherry - Northern Hardwood Forest
DD	Aspen / Gray (Paper) Birch Forest
FB	Hemlock (White Pine) - Northern Hardwood Forest
FA	Dry White Pine (Hemlock) - Oak Forest
FR	Hemlock (White Pine) - Red Oak - Northern Hardwoods
TM	Tuliptree - (Beech) - Maple Forest
CS	Sugar Maple - Basswood Forest
MM	Mixed Mesophytic Forest
FF	Hemlock (White Pine) Forest
EO	Pitch Pine - Mixed Oak Forest
GB	Black Gum Ridge Top Forest
LB	Black Locust Forest
FT	Hemlock - Tuliptree - Birch Forest
EV	Virginia Pine - Mixed Oak Forest
FM	Hemlock - Rich Mesic Hardwood Forest

An example…

20 Forest Types (i.e. Communities)

ID	Descriptive Name
AH	Dry Oak - Heath Forest

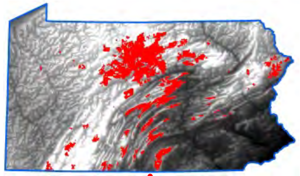
The goal is to quantitatively link the occurrence of these communities to measures of the underlying environmental conditions.

What controls the distribution of these community types in space?

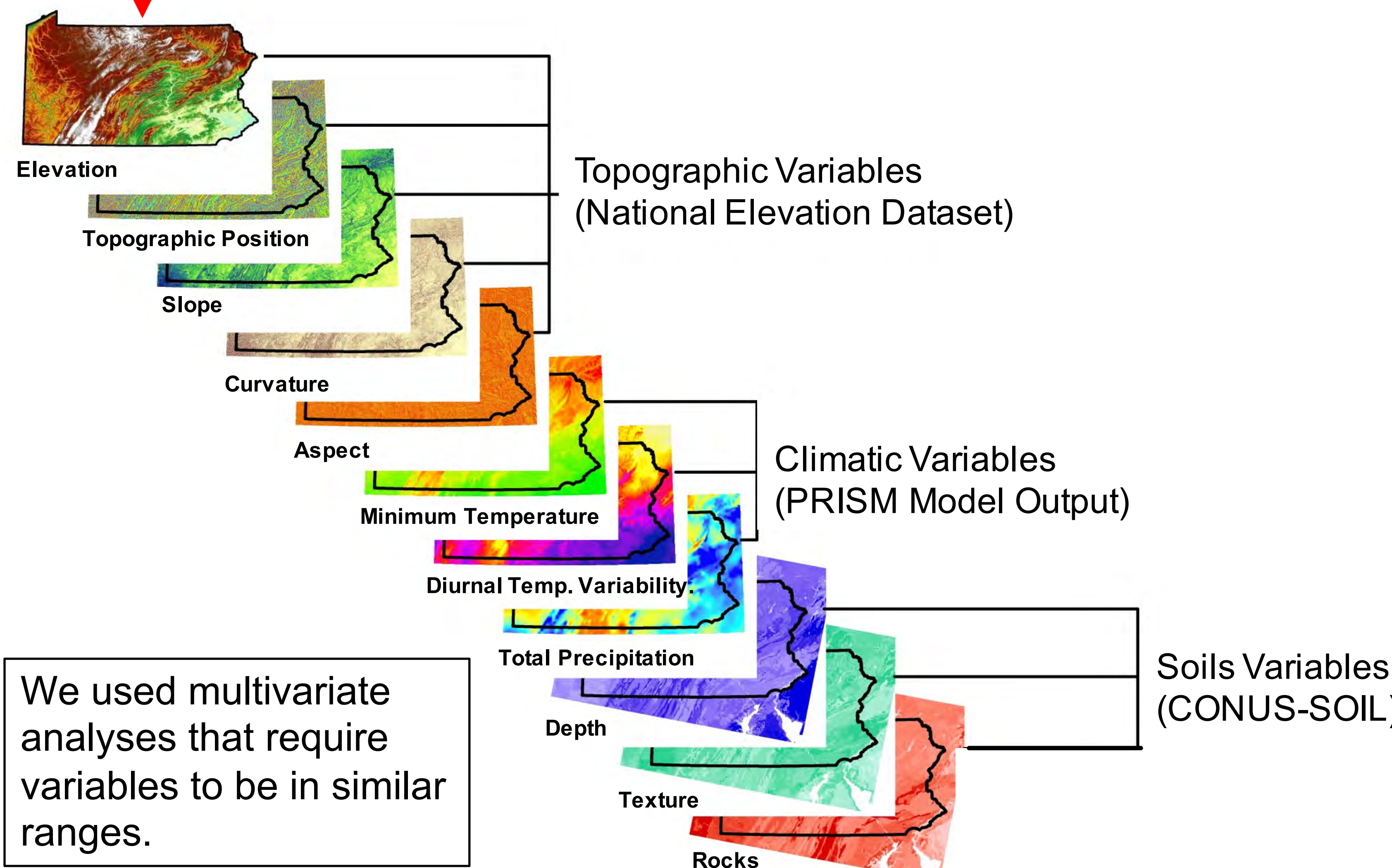
Which ones are closely related with respect to environmental preferences and which are not?

Which ones get lumped into an Ecological Site?

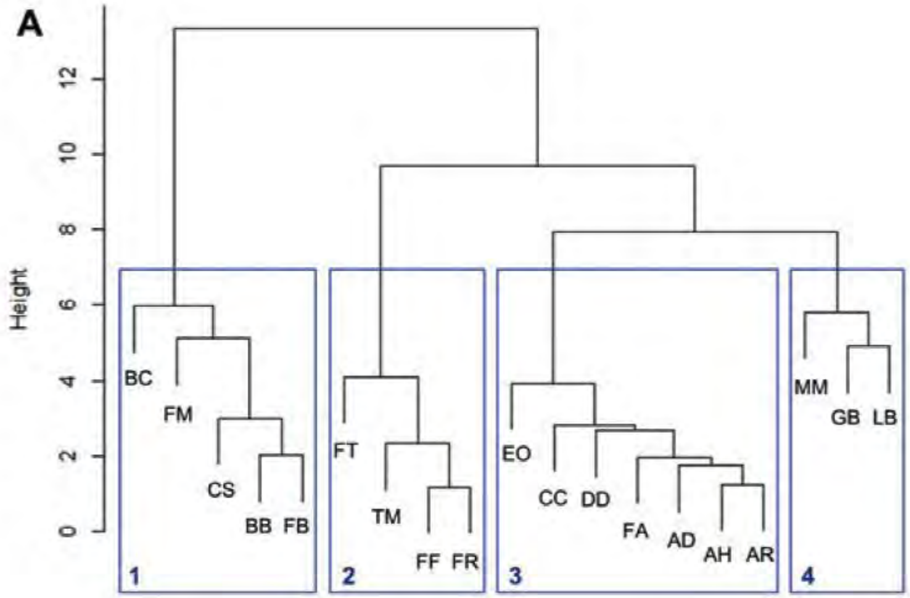
Methods

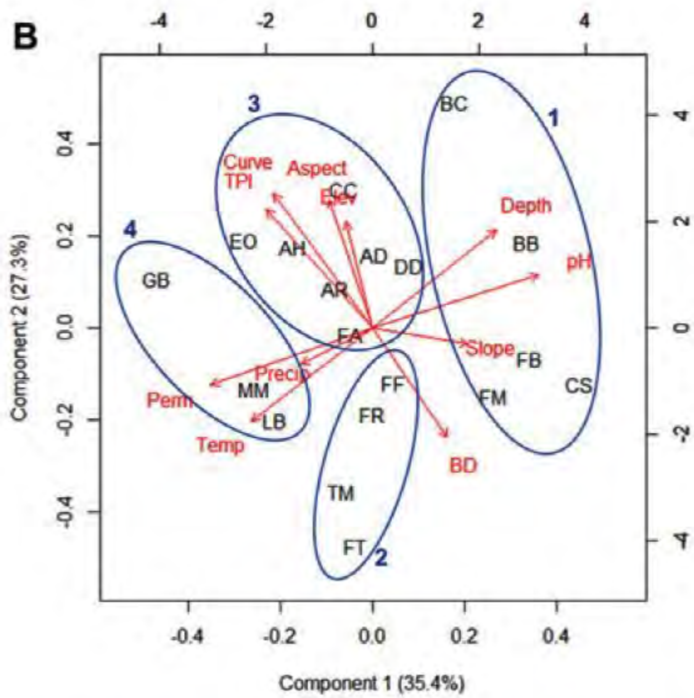


One random point per forest type polygon (n=58,261), repeated seven times



We used multivariate analyses that require variables to be in similar ranges.





AD	Dry Oak - Mixed Hardwood Forest
AH	Dry Oak - Heath Forest
AR	Red Oak - Mixed Hardwood Forest
BB	Northern Hardwood Forest
BC	Black Cherry - Northern Hardwood Forest
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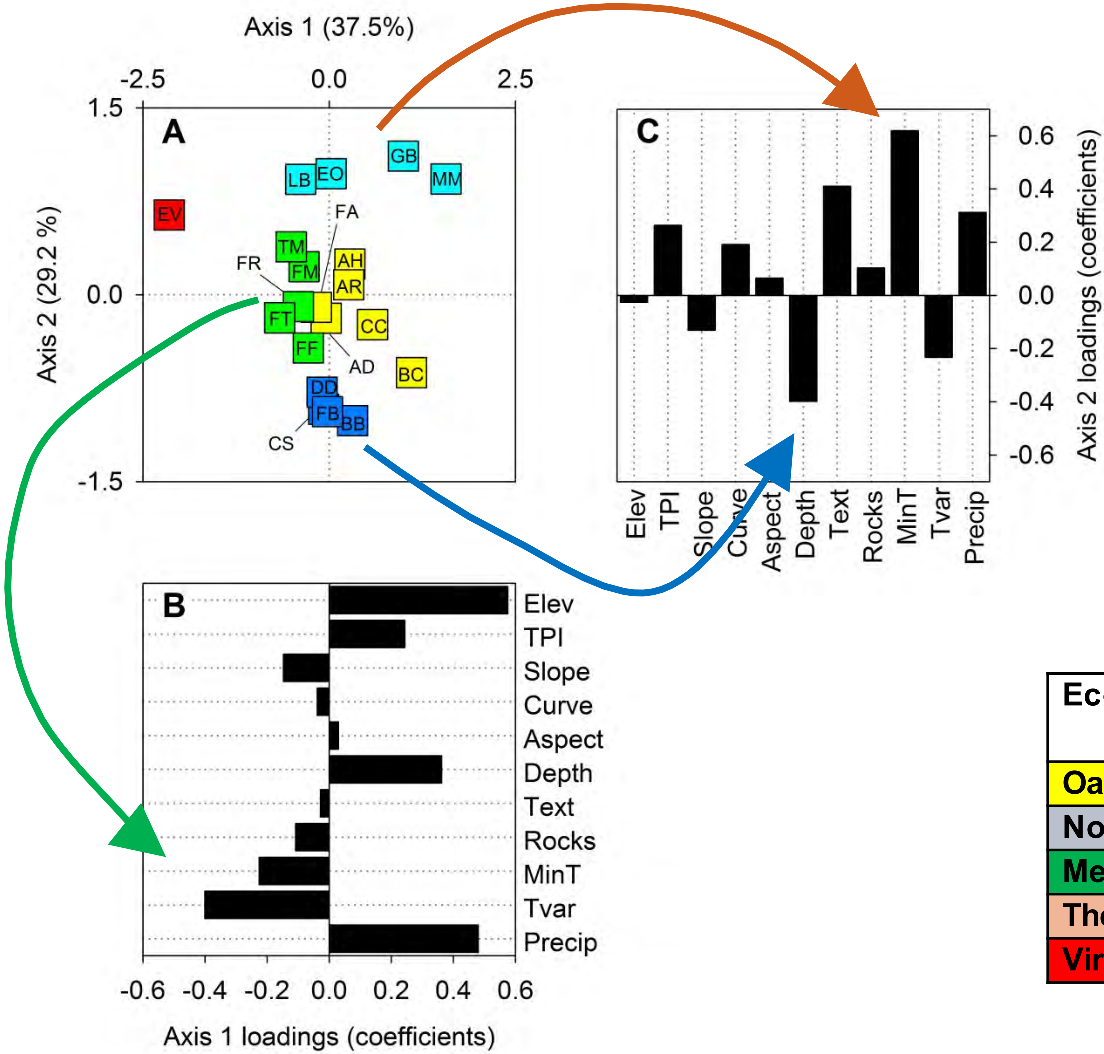
(a) Results of hierarchical cluster analysis (Ward's method, Euclidian distance). Forest stand types are grouped based on z-score standardized mean values for each of the 11 environmental variables. Groups arbitrarily numbered 1 through 4, left to right.

(b) Principal components analysis of the same data set used in clustering. Blue ellipses outline cluster analysis groups. Vectors in red represent loadings of environmental variables in two-dimensional ordination space.

Results

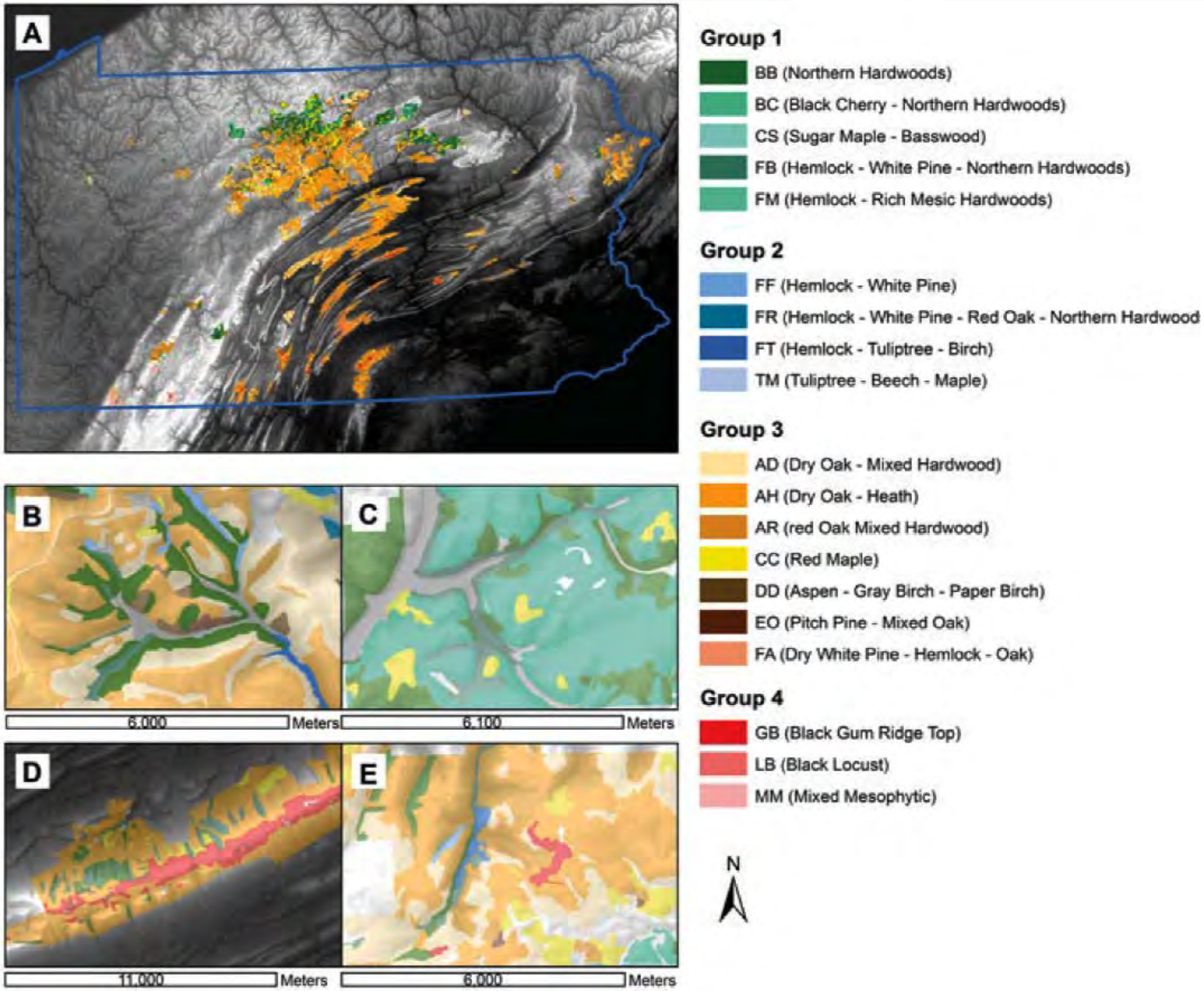


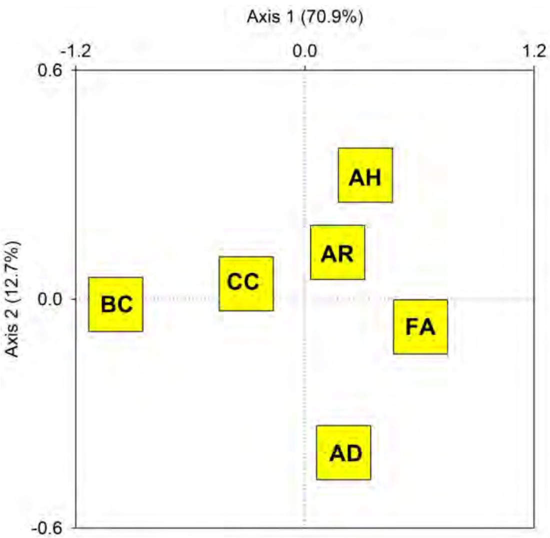
The **Northern Hardwoods Forests** are strongly associated with deep soils, steep slopes, and high diurnal temperature variability (axis 2).

Ecological Site	Area (ha)
Oak – Maple - Hardwoods	581,404
Northern Hardwood Forests	197,831
Mesic Hemlock Forests	19,308
Thermophilic Forests	15,618
Virginia Pine Forests	692

Table 3. Draft names, number of constituent forest stand types, and area occupied for each of the four preliminary Ecological Sites.

Group†	Draft names for preliminary Ecological Sites	Number of forest stand types (states or phases)	Area (ha)
1	deep soil, high slope, northern hardwood forests	5	214,887
2	lowland, mesic hemlock-dominated forests	4	18,889
3	dry upland oak–maple–hemlock–hardwood forests	7	569,216
4	high temperature, high precipitation, high soil permeability forests	3	11,176





BC = Black cherry
CC = Red Maple
AH = Dry Oak - Heath
AR = Red Oak – Mixed Hardwood
FA = Dry white pine – Oak
AD = Dry Oak – Mixed Hardwood

Big Picture Summary

We developed a defensible, reproducible methodology

We developed ESs over 815,000 ha

We found robust patterns in the data

Next, develop the STMs

http://www.dcnr.state.pa.us/forestry/whatwedo/index.htm

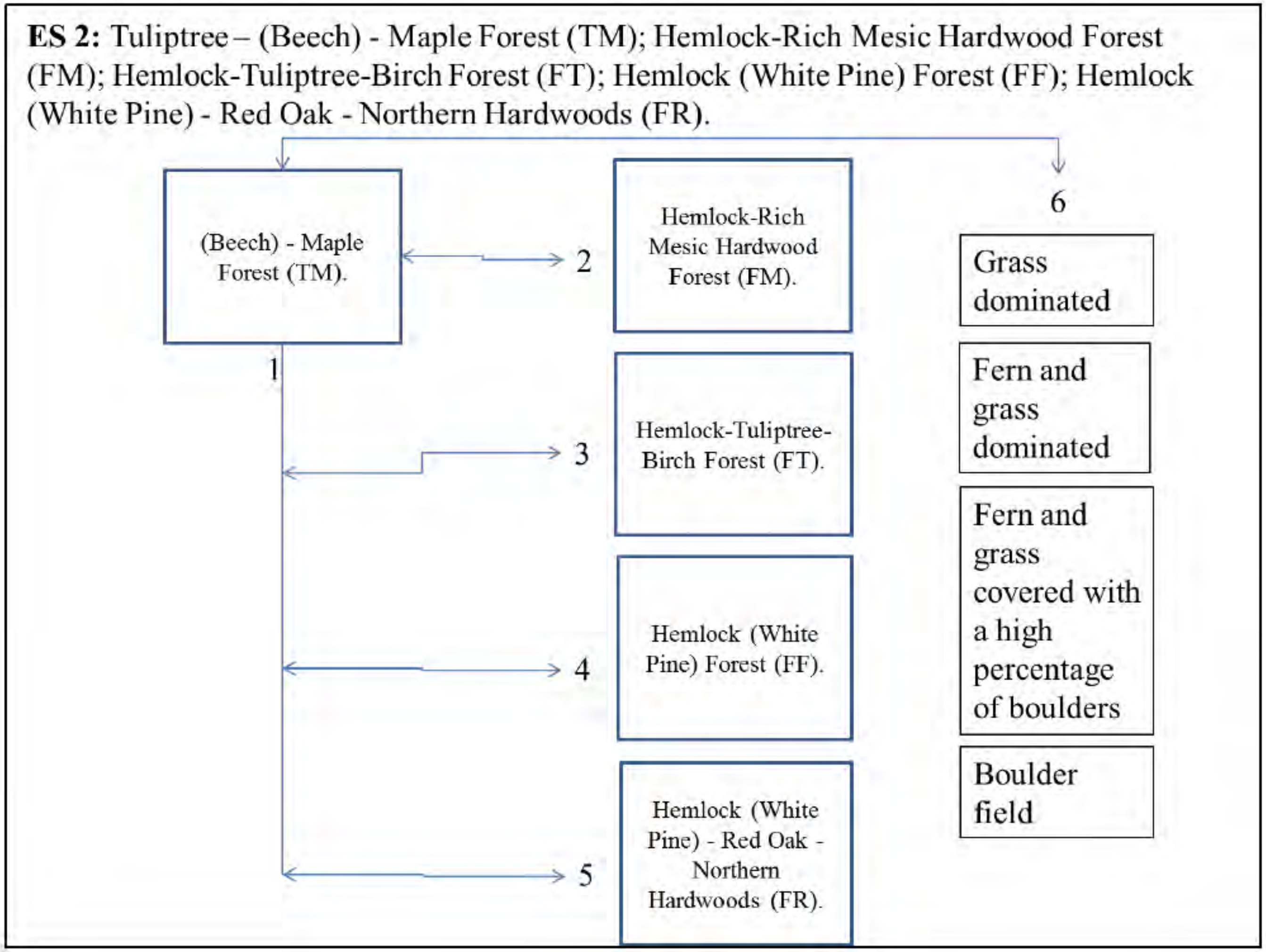


Figure 3. State and Transition model for Ecological Site 2. Box to the right describes the phases and their potential transitions. Community codes refer to Fike (1999).

1 This phase is largely a product of anthropogenic management. It can occur anywhere any of the other phases occur.

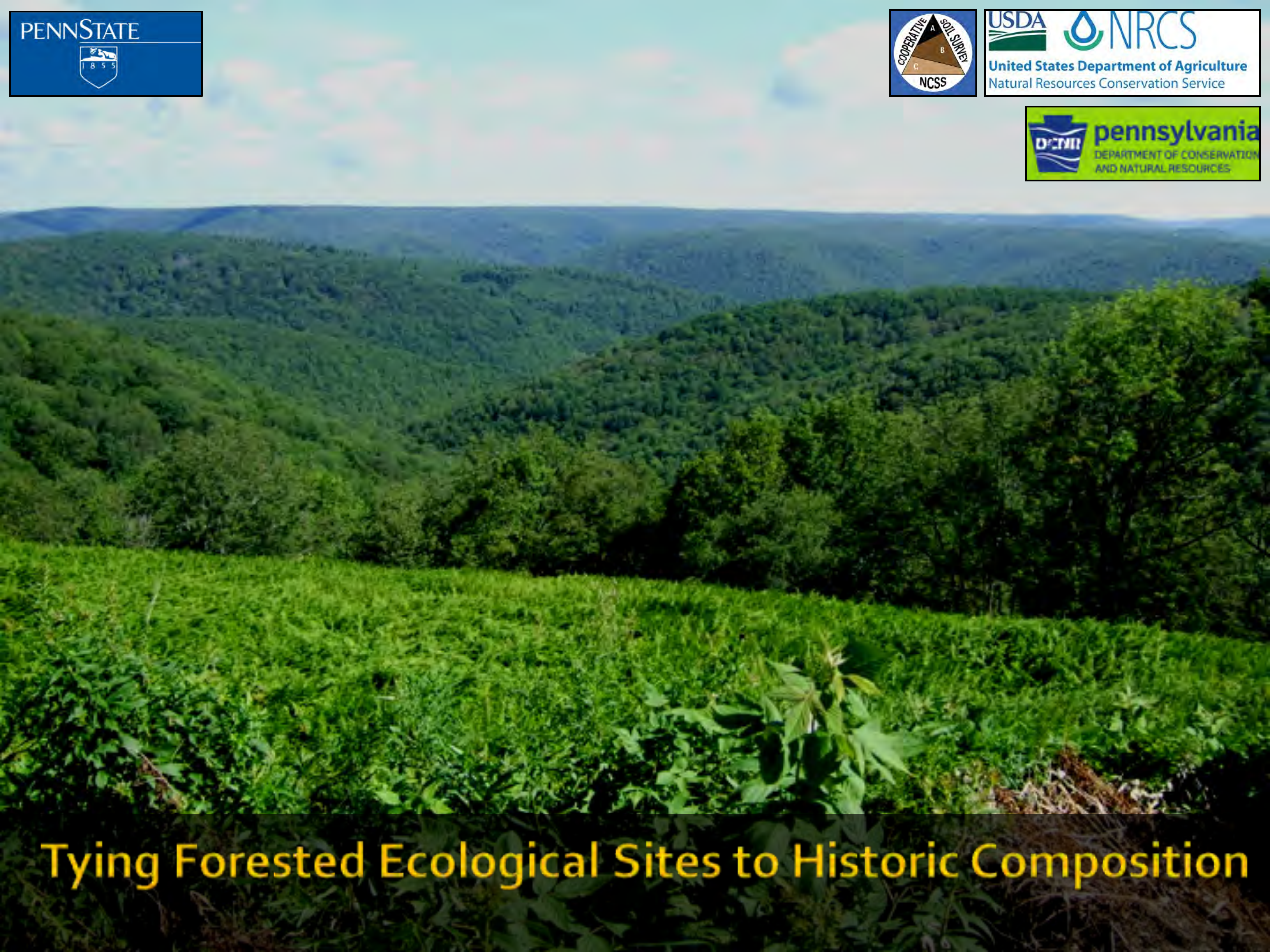
2 This phase is more typical of lower slopes and may be a candidate for a separate Ecological Site. It is similar to the Mixed Mesophytic Forests (MM) in southern areas of the MLRAs and the Valley and Ridge. However, this phase is more likely an indicator of climate change.

3 The influence of southern species and red oak separate this phase from 4. This phase may predominate lower slope areas or coves.

4 This phase borders the Northern Hardwoods and is very extensive through both MLRAs. Many hardwood species (American beech and red maple) are a result of anthropogenic management.

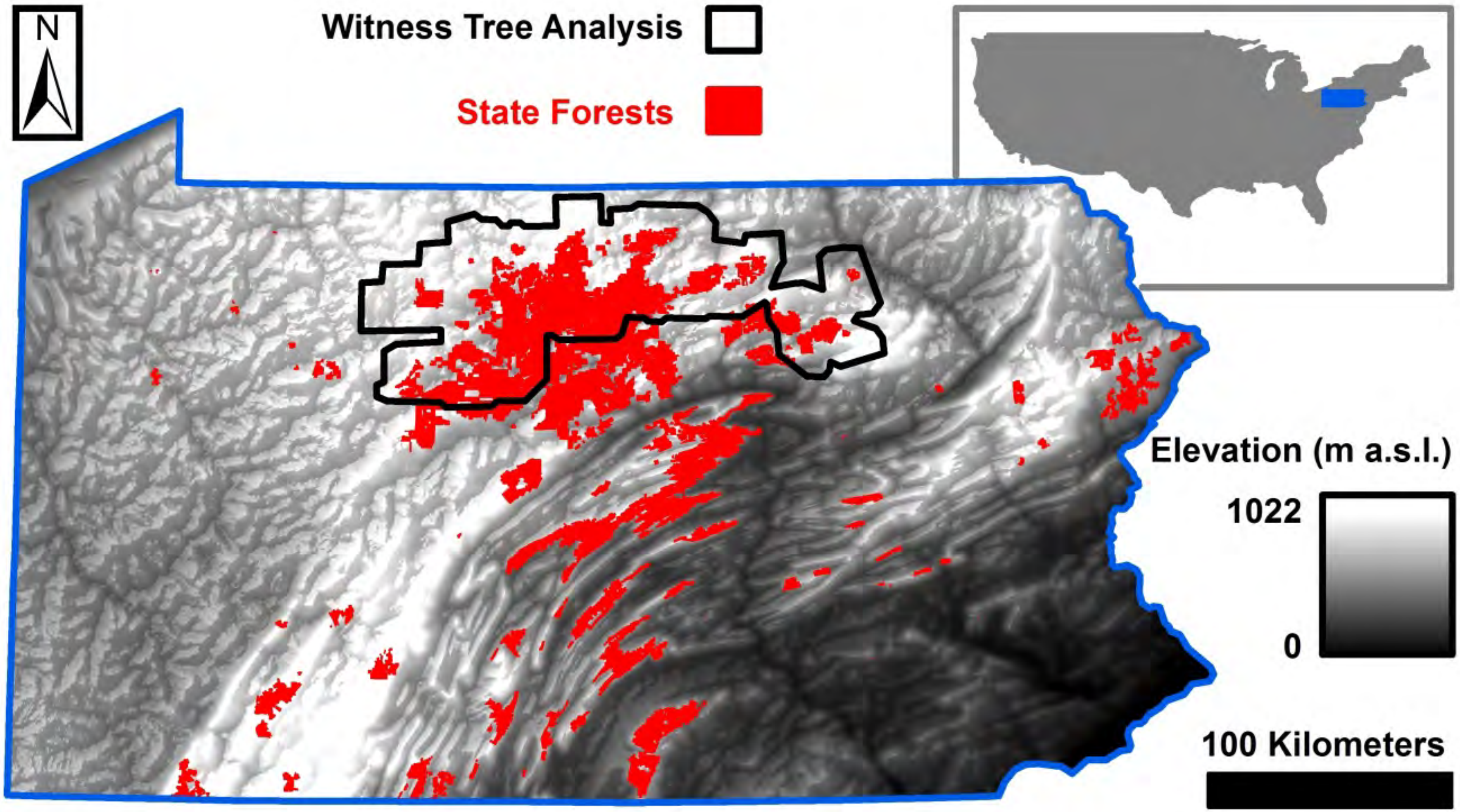
5 This phase is similar to AR in Ecological Site 4 but has eastern hemlock and white pine contributing more than 25% cover. This Phase may be a relict of a nearly dominant white pine stand that was present following early harvesting.

6. Depending on site history (fire intensity, erosion, timber regeneration failures, anthropogenic disturbance) any of the following types are possible. Boulder fields may be relict of the region's former periglacial climate.



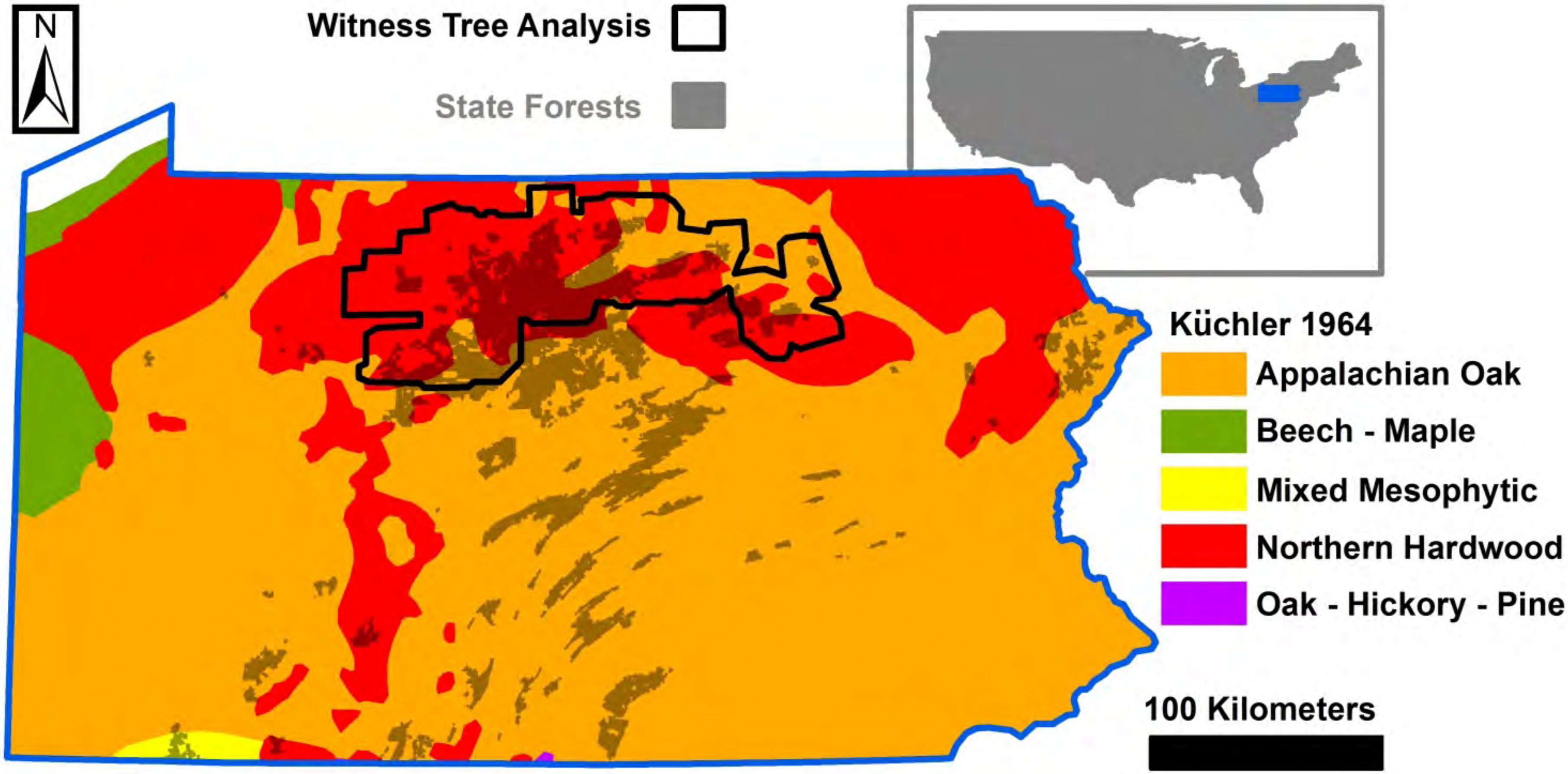
Tying Forested Ecological Sites to Historic Composition

Study Area, Witness Trees

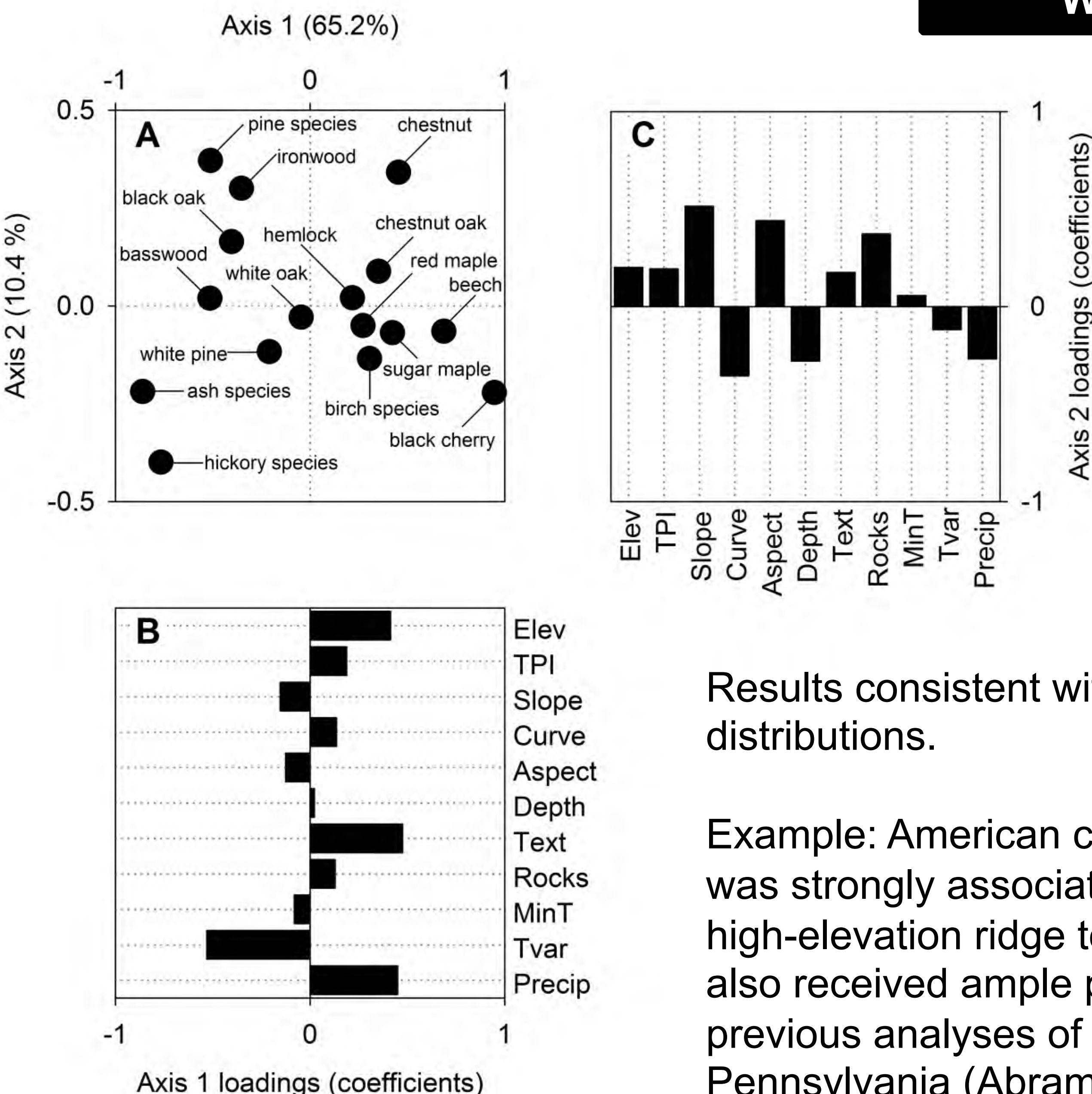


Data 49 Townships from the late 1700s
2,699 were trees identified to at least the level of genus.
Of these 2,699 trees, 716 occurred on Ecological Sites we mapped.

Study Area, Witness Trees

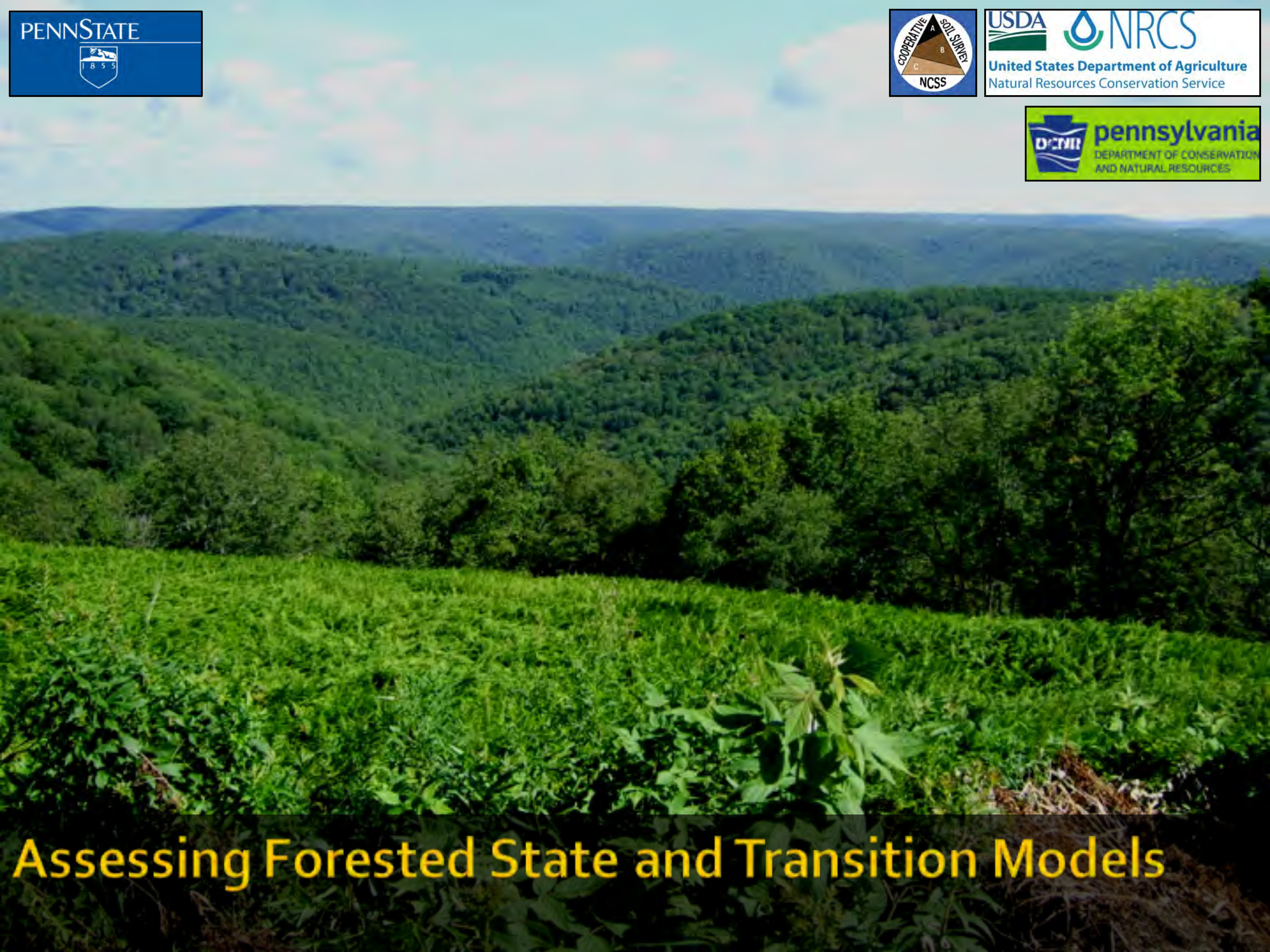


Witness Tree Data



Results consistent with historic literature distributions.

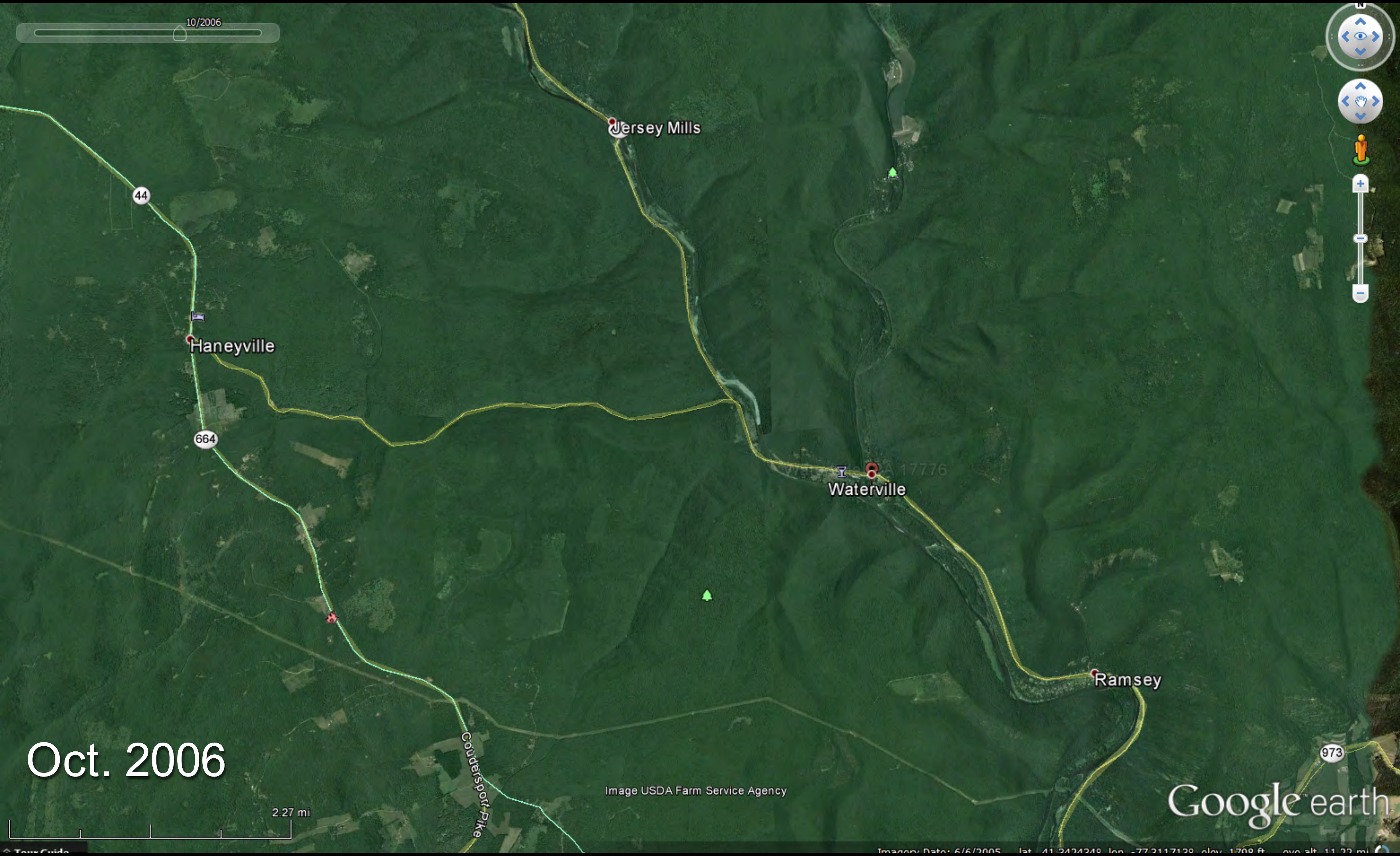
Example: American chestnut (*Castanea dentata*) was strongly associated with south-facing, steep high-elevation ridge tops with course soils that also received ample precipitation. consistent with previous analyses of witness tree data in Pennsylvania (Abrams and Ruffner, 1995),



Assessing Forested State and Transition Models

Primary Drivers of PA Forest Change

Tiadaghton State Forest

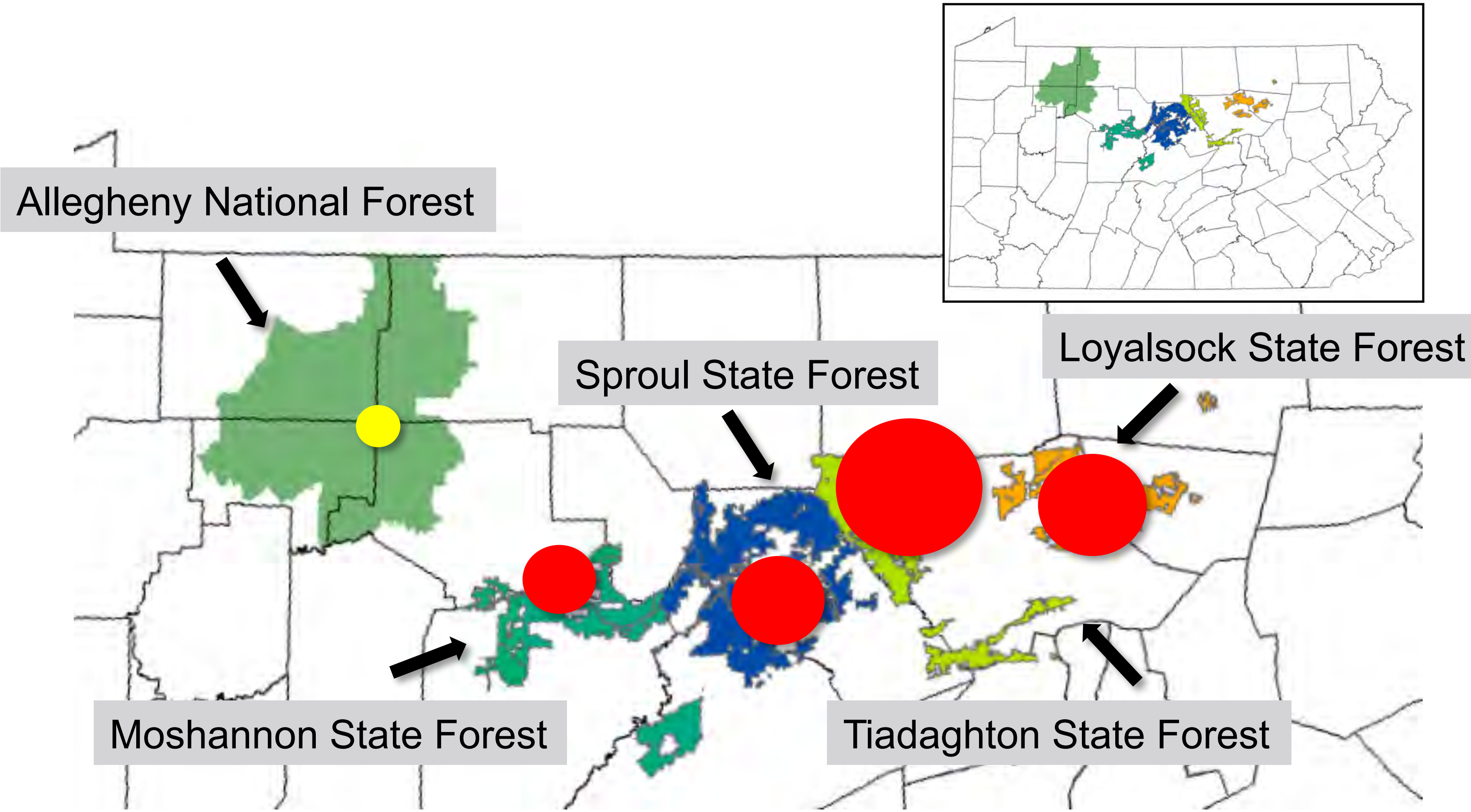


Tiadaghton State Forest

Research Questions

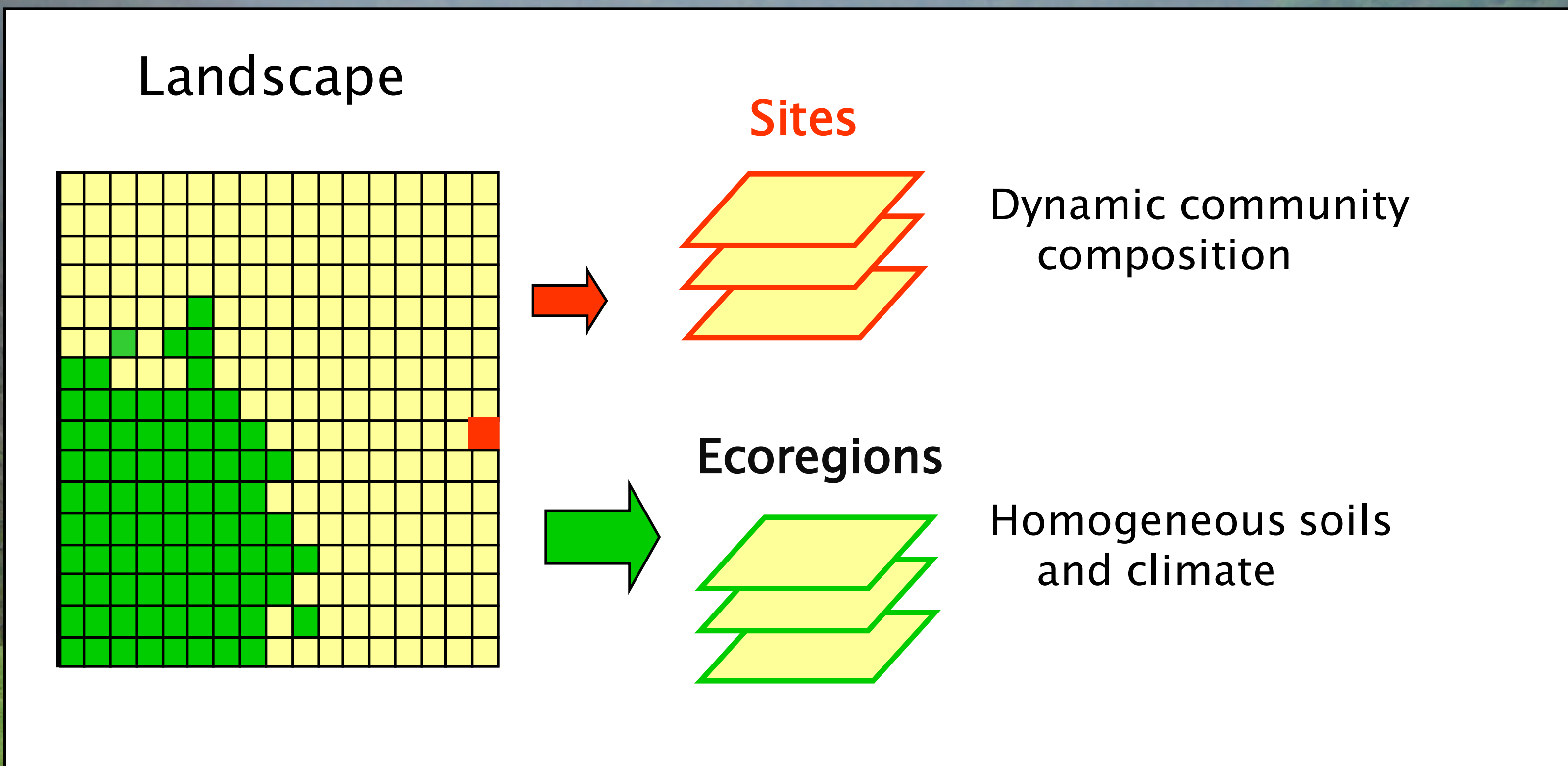
- What is the effect of unique disturbance drivers on forest composition change (spp, biomass).
- What are the combined effects of any two, three…?
- What is their cumulative impact?

Pennsylvania Simulation



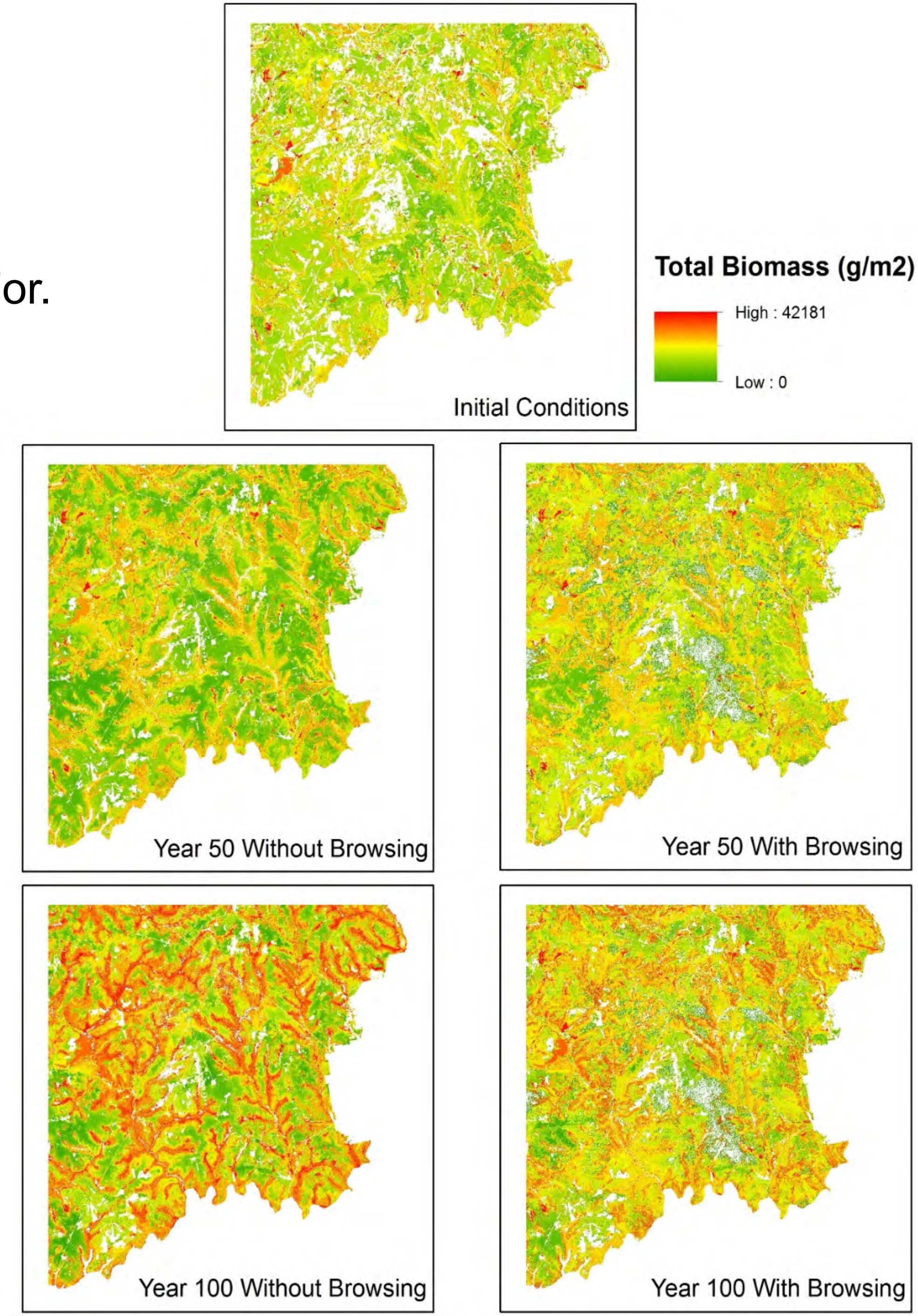
LANDIS-II Modelling

LANDIS simulates succession, seed dispersal, harvesting, and other natural disturbances.

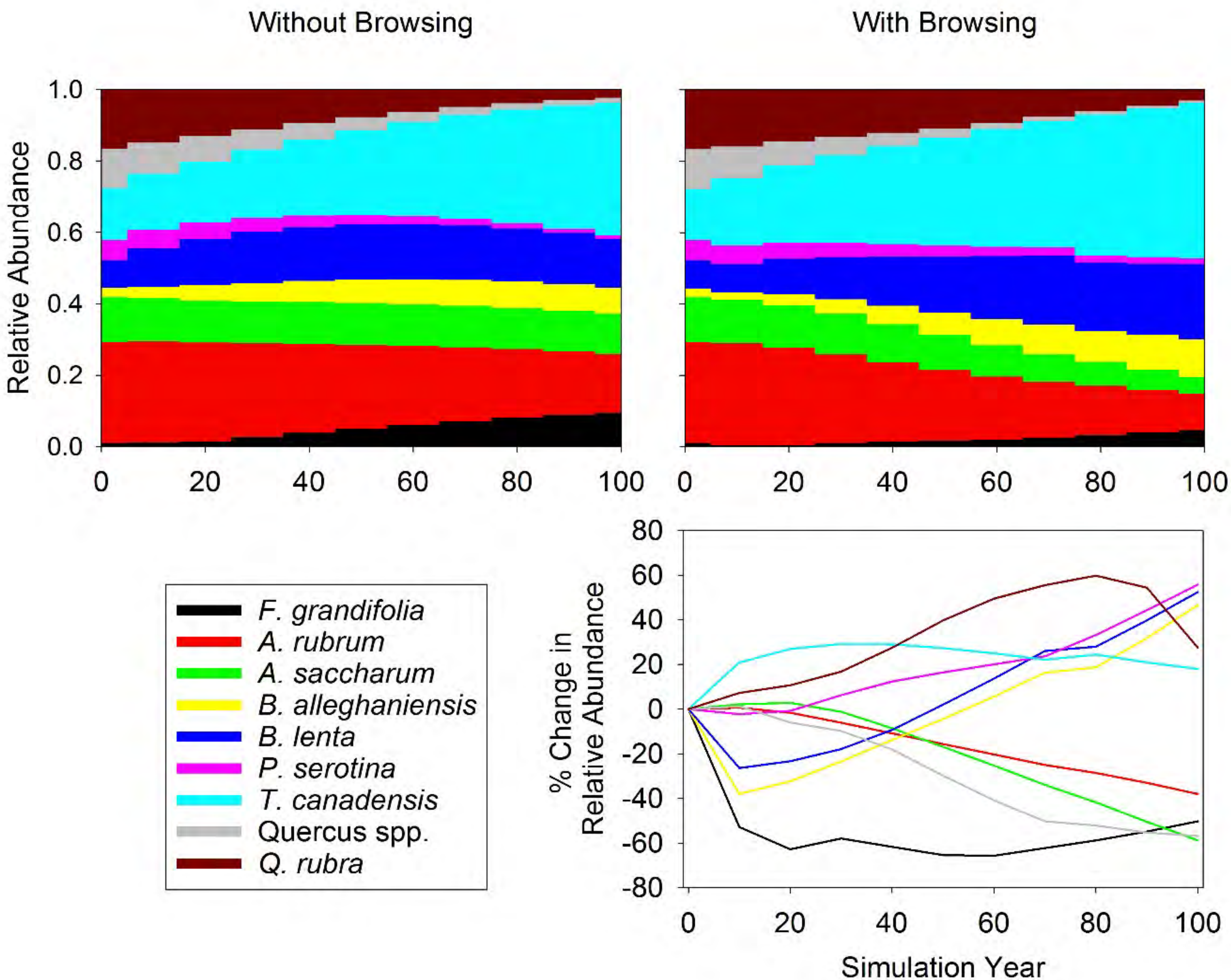


Courtesy Rob Scheller

Southeast Allegheny Nat. For.



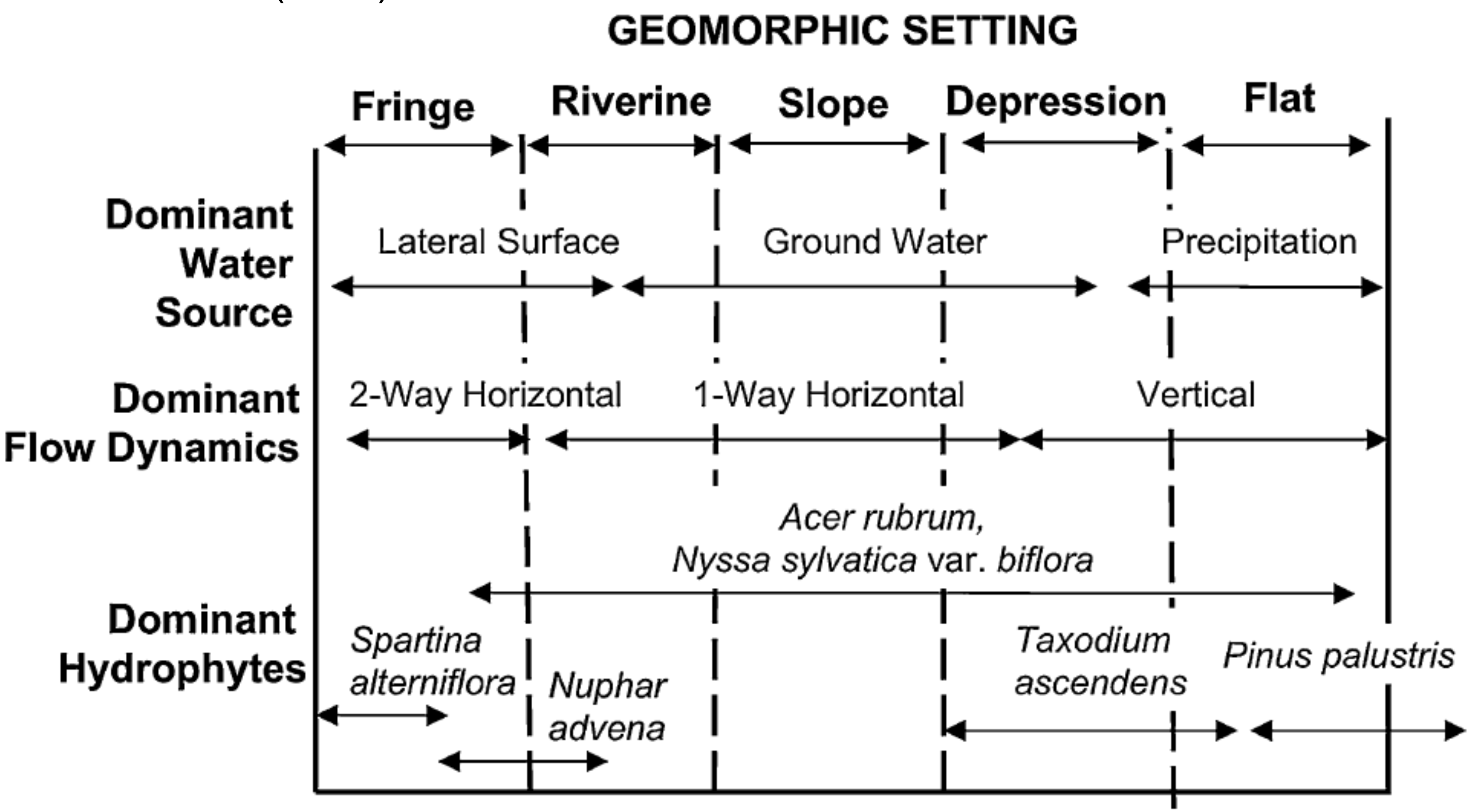
Southeast Allegheny Nat. For.



Identifying Wetland Ecological Sites

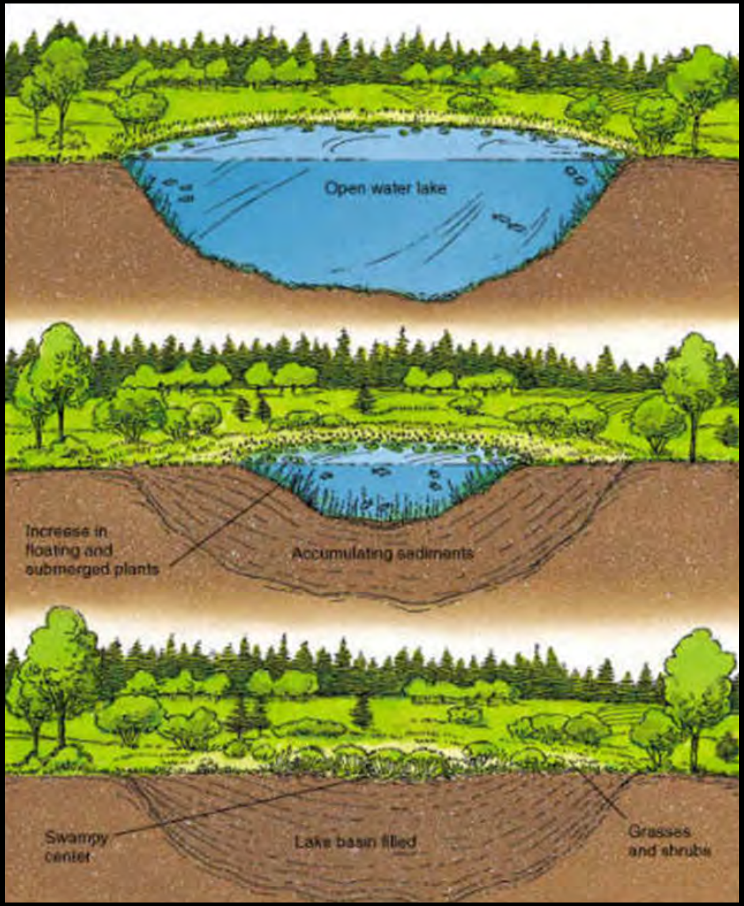
Current Work....Wetlands

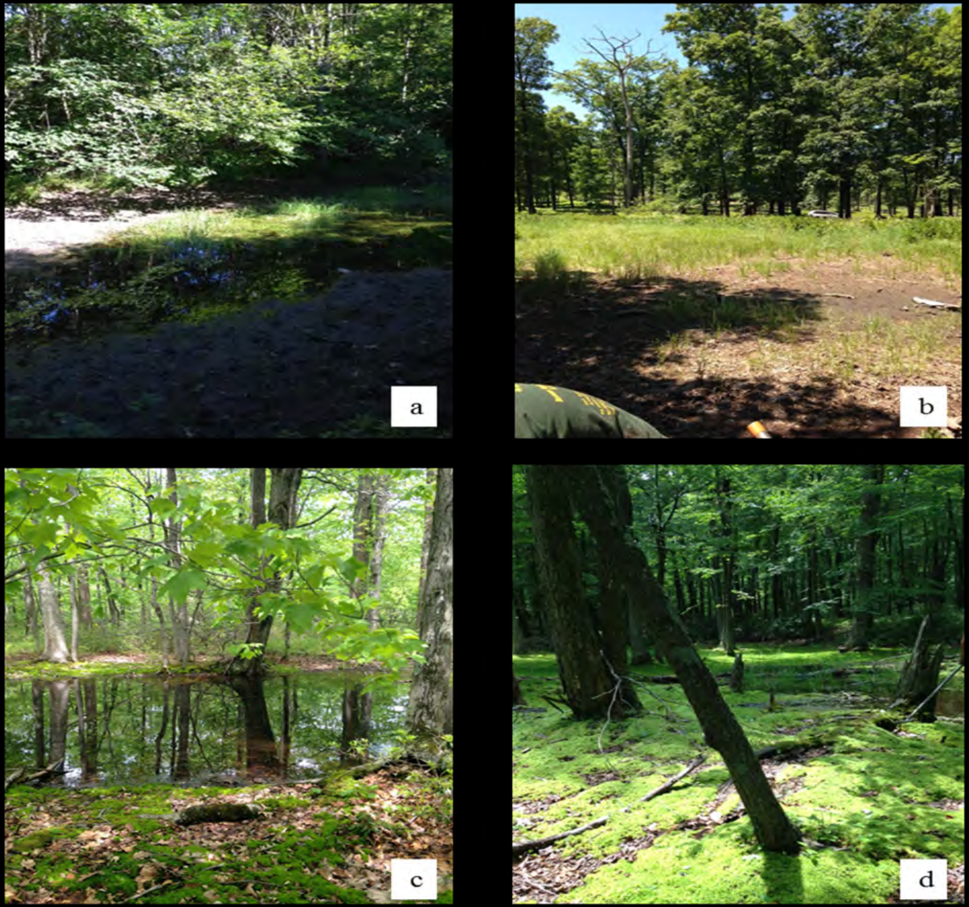
Fig. 2: The relationship of geomorphic settings and dominant waters source and flow dynamics. Some dominant hydrophytes span several geomorphic settings.
Brooks et al. (2012)



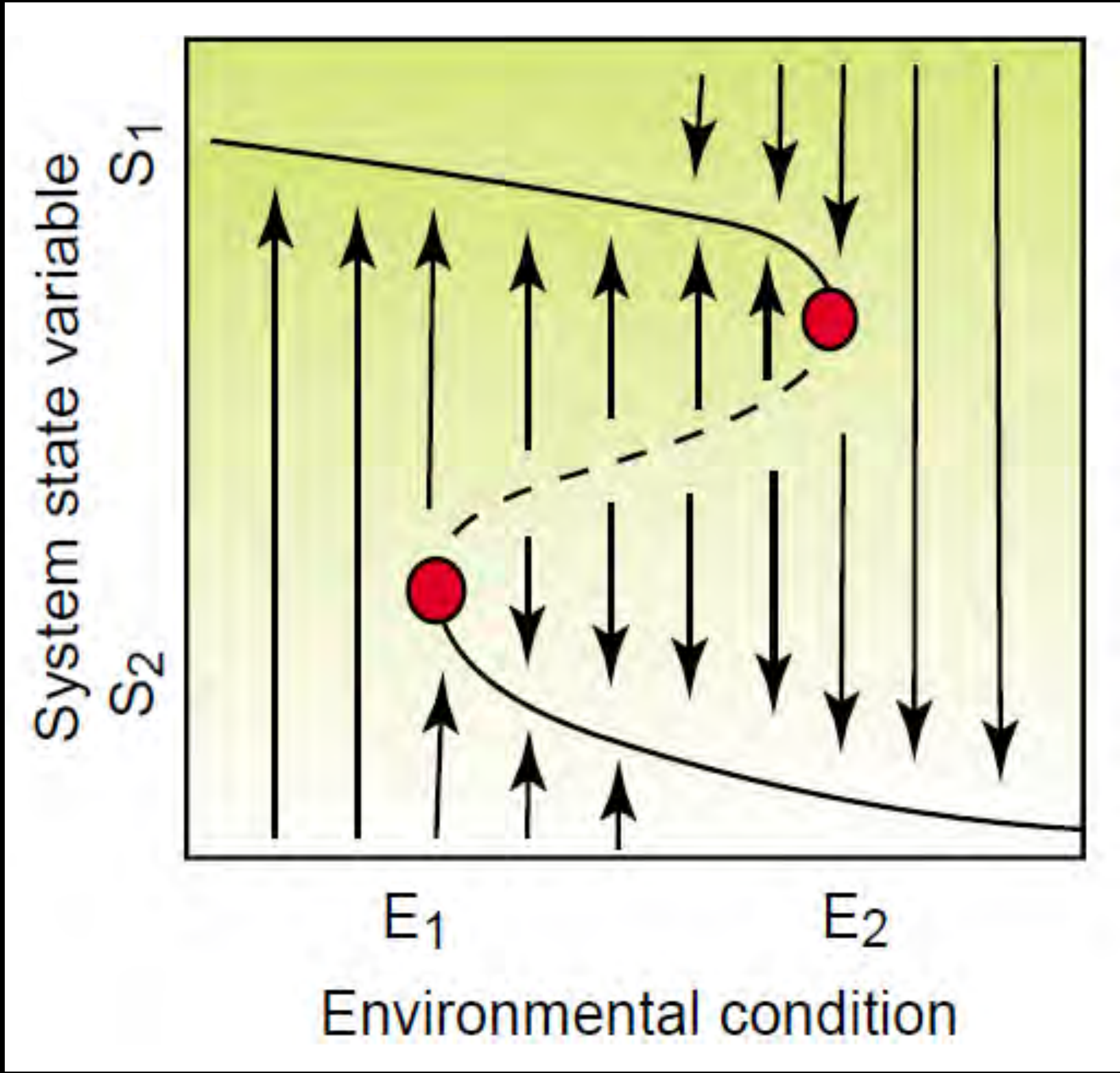
Eight Potential Field Sites

NONEQUILIBRIUM CARBON DYNAMICS IN ALTERNATIVE STABLE STATES OF VERNAL POOLS





Shauna-kay Rainford



The principal thesis of alternative state models is that the system can shift abruptly between two or more states

Fig. 1. Suding et al. (2004)

Alternative State Models and Vernal Pool Dynamics

Disturbance

- Plant population metrics
- Plant residues (pollen, photoliths, seed)
- Hydrodynamics
- Rates of soil accumulation
- Soil accumulation thickness
- SOC partitioning due to plant morphology shifts with shifting spp.
- Biogeochemistry

Chapter 1

- Determine the quantity and distribution of the labile and recalcitrant soil organic carbon fractions in the top 45cm of the soil profile.
- Examine patterns of bryophyte species richness and biomass to determine whether they correlate with the quantity of soil organic fractions in the A horizon.
- Examine relationships among nutrient availability, bryophyte species richness, and biomass of bryophytes

Chapter 2

- Develop stratigraphic indices of a warming climate for vernal pool sites located in the glaciated and non-glaciated regions of Pennsylvania utilizing soil morphology, pollen stratigraphy, pollutant metal concentrations, and ^{14}C dates.
- Reconstruct palaeoecological records using charcoal, pollen, and organic matter content of vernal pool sites to reconstruct spatial and temporal dynamics of vernal pool genesis and development.

Thank You